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No. 1. — *Birds of the Cape Region of Lower California.*

By William Brewster.

INTRODUCTION.

In 1887 Mr. M. Abbott Frazar spent about nine months collecting for me in Lower California. During this period he obtained upwards of 4,400 birds, among which were several new to science, besides a number hitherto unknown from the Cape Region. Of the quality of his specimens and of the industry and intelligence which he displayed in collecting them it would be impossible to speak too highly. Indeed, it is probable that no collection of equal size and excellence was ever before accumulated by any one man within so short a space of time. The skins are beautifully prepared, and the series representing the resident or more characteristic Cape birds are sufficiently large to illustrate very fully the individual, as well as age and seasonal, variations to which each form is subject. Mr. Frazar failed, however, to secure many nests or eggs and — what is even more to be regretted — his field notes, descriptive of the localities which he visited and of the habits, behavior, and songs of their most interesting birds, are, in most respects, disappointingly brief and inadequate. I have culled from his journals and from the evidence supplied by his specimens, every fact or suggestion which has seemed worthy of permanent record, and I have supplemented the matter thus obtained by drawing freely on the published accounts of other observers who have visited the same region, among whom Mr. Xantus, Mr. Belding, Mr. Bryant, and Mr. Anthony are, of course, the most prominent.

The biographical material gathered from these sources includes, I trust, all the information of obvious value and pertinence which is at present accessible, but it is undeniably inconsiderable in quantity and colorless in character. The simple truth is that the ornithologists who have thus far visited Lower California have devoted most of their attention to collecting and preparing specimens and but very little to making, or at least recording, field observations. Thus it happens that while we have much definite knowledge respecting the physical characteristics and affinities of the birds of this region, as well as not a little concerning their respective areas of local occurrence or distribution, we know almost nothing of their habits, songs, and distinctive appearance or behavior when living. The nests and eggs of many of them also remain undescribed. In short, the time has not as yet arrived when anything more than the merest outlines of their life histories can be sketched.

The main portion of my paper treats only of birds which are definitely known to have occurred in the Cape Region, but in dealing with the distribution of such of these as are not confined to this area I have consulted — and frequently cited, also — all the more important records that I could find relating to the central and upper parts of the Peninsula as well as to southern California, and in addition I have outlined, briefly, the general range of each species or subspecies along the Pacific coast, hoping thereby to show more clearly the precise relations in which the different forms stand geographically to the Cape fauna.

Most of the strictly biographical matter relates either to birds which are peculiar to, or characteristic of, the Cape Region or to observations made within the limits of this territory, no attempt having been made to present life histories of those species which occur as migratory or winter visitors only. Exceptions to this rule have been made, however, in the cases of certain of the water birds whose breeding stations lie at no great distances, or whose breeding habits are of especial interest.

From this it will be gathered that my part in the work has been chiefly that of a compiler of facts observed or recorded by others, but I have personally contributed some original matter in the form of technical description and critical comment. In connection with my efforts to unravel some of the more difficult problems affecting the status or relationship of certain of the less well known birds I have received invaluable assistance from my friend Mr. R. Ridgway, who has supplied me with whatever specimens I have needed for comparison (including several types) from the collections of the United States National Museum, and to whom I am further indebted for much kindly encouragement and advice. I am under obligations, also, to Mr. E. W. Nelson, who has been kind enough to read my paper in the manuscript and to favor me with criticisms or suggestions, which have proved of the utmost service. Nor should I omit in this connection to express my thanks to Dr. J. A. Allen and Mr. F. M. Chapman, for the opportunities which they have given me of examining specimens preserved in the collections of the American Museum, and to Dr. C. Hart Merriam, Mr. Samuel Henshaw, Mr. Walter Faxon, Mr. Harry C. Oberholser, and Dr. Charles W. Richmond, for assistance of various kinds. In short, all these as well as others of my friends have responded most generously to the calls which I have made upon them.

The task of preparing the synonymy has been intrusted to my assistant, Mr. Walter Deane, who has performed it with infinite care and faithfulness, verifying every citation by direct examination of the original text. A fuller synonymy has been given for the thirty or more birds which appear to be either peculiar to the region under consideration or especially prominent members of its summer fauna, but in the cases of most of the others Mr. Deane has cited only publications which relate more or less directly to this region, giving no references to the more general works on ornithology save where these include original descriptions, illustrations, or critical discussions strictly pertinent to the subject in hand. In other words, the synonymy is intended to serve, at least primarily, merely as an index to what has been published on the characteristic birds of the Cape Region, and on the *local history* only of those which visit it during migration or in winter, or which breed but casually or very sparingly within its confines.

All the original measurements are in inches and hundredths of an inch.

Cape Region of Lower California.

Mr. Bryant[1] defines this region as comprising " that terminal portion of the peninsula southward from the northern base of the mountains between La Paz on the Gulf shore and the town of Todos Santos on the Pacific Coast." He adds, " There is no more sharply defined faunal and flora area, that occurs to me now, excepting that of islands, than is embraced in the region above defined. Part of it lies within the Tropic of Cancer, and the balance along the Gulf shore, and having mainly a Gulf drainage. The climate as influenced by its peculiar sea-bound tropical situation and rainy seasons is distinctively different from anything existing to the northward. . . . Mainly a mountainous section, some of the peaks being 6,000 feet high, it is separated for an hundred miles or more from the peninsula northward by a long expanse of low, level or rolling country."

Mr. T. S. Brandegee writes me : "In reply to your question concerning my limitation of the Cape region, I will answer that for the flora it seems best to include only the region south of a line between La Paz and Todos Santos. This line is nearly a straight line, and follows along the northern base of the Cape Mountains. The trail between La Paz and Todos Santos does not appear to ascend more than 150 feet above sea-level at any place, and there is a large extent of nearly level country to the north of it. The Cape Region will be, then, a mountainous country separated from the northern mountains by an extent of low land."

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[1] Zoe, II. 1891, 185, 186.

The depressed and exceedingly arid desert tract above mentioned evidently forms nearly as complete a barrier to the northward and southward extension of plant and animal life as would a similar expanse of ocean. Indeed, there can be little doubt that the comparative isolation which its presence affords to the region lying to the southward has had very much to do with the striking faunal and floral characteristics of the latter area. Another factor of perhaps almost equal potency is the comparatively humid climate of the Cape Region with the resultant (but also only comparative) luxuriance of its vegetation.

The limitations so concisely yet clearly stated by Mr. Brandegee are those which I have adopted in the present paper, but I have ventured to construe these (wholly without his knowledge or sanction) as including the island of Espiritu Santo, whose fauna, judging by what little we know of it, seems to be essentially similar to that of the region lying about and to the southward of La Paz.

It was my original intention to insert in this connection some generalizations bearing on the characteristics and affinities of the fauna and flora of the Cape Region, as well as to tabulate the names of its various birds in lists of permanent residents, summer residents, winter residents, migratory visitors, etc., but I have found so very many cases where all the information at my command has proved insufficient to enable me to reach definite conclusions, that I have become convinced that the time has not as yet arrived when it is either safe or profitable to attempt anything of the kind just indicated; I may venture to say in passing, however, that, as Professor Baird pointed out in 1859, the characteristic birds of the Cape Region appear to be more closely related to those of Arizona and Northwestern Mexico than to those of California, although certain recent developments have shown that this rule is not wholly without exceptions.

NARRATIVE.

Gulf Trip. — Landing at La Paz on January 24, Mr. Frazar remained in the immediate neighborhood of that place until February 26, when he embarked in a small vessel and visited successively the islands of Espiritu Santo, San José, Montserrat, and Carmen, which lie stretched out in a series or chain in the Gulf of California to the northward of La Paz and not far from the eastern coast of the Peninsula. He describes them as "all alike, very hilly, almost devoid of vegetation," and practically without water excepting where it is obtained by digging.

On Carmen Island, the largest of the series, he spent three days, during which he skirted the entire southern shore, landing at several different places. There were but few birds, and most of these were waders or water fowl. The only species of which specimens were obtained were the Large-billed, San Benito, Brewer's, and Desert Sparrows, the American Raven, the St. Lucas Sparrow Hawk, the Black-bellied and Wilson's Plovers, the Least and Spotted Sandpipers, Frazar's Oystercatcher (of which two specimens, including the type, were taken here), the Western and Heermann's Gulls, the Farallone Cormorant, and the American Eared Grebe. In addition to these Mr. Frazar mentions seeing a Western Mockingbird, a few Verdins and Gnatcatchers, an Orange-crowned Warbler, one or two Costa's Hummingbirds and a number of Fish Hawks.

On March 10 Mr. Frazar landed on the shore of the Peninsula opposite Carmen Island, and proceeded inland some three or four miles to the base of the Victoria Mountains,[1] crossing a belt of country covered with dense brush and having much the same bird fauna as the region immediately about La Paz, save that a number of the species which occur at the latter place were apparently wanting in this locality.

The next day was spent in a ravine some three miles in length, which penetrates deep into the heart of the mountains, and forms the course of a slender, trickling stream, the only running water, it was said, which at that time existed among these mountains. Here he found a flock of Arkansas Goldfinches, considerable numbers of Xantus's Hummingbirds, a female Allen's Hummingbird, a few pairs of Black Pewees, a Phainopepla, and a Sharp-shinned Hawk, besides many species (none of which are enumerated) which he had previously noted at La Paz.

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[1] A subgroup or chain of the Sierra de la Gigantea range, not to be confounded with the Victoria mountains south of La Paz.

On the 12th he went to Loreto, where a day devoted to collecting yielded only two or three specimens each of the Titlark, Black-bellied Plover, and Turnstone.

The return trip to La Paz was made in an open canoe, for the first half of the distance along the shores of the Peninsula, thence by way of San José and Espiritu Santo Islands, on both of which Mr. Frazar landed. He characterizes them briefly as "like the other islands," but adds that the coast line of Espiritu Santo is broken in a few places by small inlets bordered by mangroves. It will be remembered that the type specimen of Belding's Rail was obtained on this island, no doubt in one of the little inlets just mentioned.

During the expedition the following water birds were noted: —

1. American Eared Grebe. Common about Carmen Island, March 6–10.
2. Craveri's Murrelett. On March 1 numbers were found off the western shore of San José Island. None were seen here during the return trip, but on March 15 a good many were met with near the northern end of Espiritu Santo Island. The species was observed *only* on these two occasions.
3. Heermann's Gull. Two breeding colonies were visited, one on a small rocky island between Loreto and Carmen Island, on March 13, the other on Montserrat Island the following day. In both localities the birds had only just begun laying their eggs.
4. California Gull. A number of birds, most of them in immature plumage, were seen migrating northward on March 13, between Loreto and Carmen Island.
5. Black-vented (?) Shearwater. Large numbers of small, dark-bodied Shearwaters, which probably belonged to this species, were seen on March 6, about midway between Montserrat and Carmen Islands. A few others of similar appearance were also observed on March 16 off the northern end of Espiritu Santo Island.
6. Least (?) Petrel. A small, black Petrel seen near Espiritu Santo Island about the last of February must have been either this or the Black Petrel.
7. Red-billed (?) Tropic Bird. A Tropic Bird noted on March 4 near the shore of the Peninsula, not far from Montserrat Island, probably belonged to this species.
8. Farallone Cormorant. About a dozen nests containing nearly full-grown young were found on Montserrat Island on March 14. The species was also seen frequently about Carmen Island.

La Paz. — At La Paz Mr. Frazar collected from January 28 to February 26, and from March 19 to April 7, making his headquarters in the town, and covering as much of the surrounding country as could be reached in a day's walk or drive. He describes it as excessively dry and barren, in fact "burnt to a crisp" by a drought, which had continued unbroken for upwards of two years. The cattle had nearly all died of thirst or starvation, for there was no surface water anywhere and no grass, the only vegetation consisting of scattered bushes and cacti of various kinds.

Over much of this desolate region birds were exceedingly scarce, but in a few favored localities — such as that at the base of the range of hills immediately behind the town, where there were exceptionally dense and luxuriant thickets of bushes and occasional small trees — Mr. Frazar found in greater or less abundance such characteristic Lower California forms as the St. Lucas Thrasher, Baird's Verdin, St. Lucas Cactus Wren, St. Lucas Swallow, St. Lucas House Finch, St. Lucas Towhee, St. Lucas Cardinal, St. Lucas Pyrrhuloxia, Xantus's Jay, St. Lucas Flycatcher, Xantus's Hummingbird, and St. Lucas Woodpecker.

Along the borders of the neighboring bay were a few scattered fringes or clusters of mangroves intersected by tidal creeks and flooded at high water. These thickets furnished congenial haunts for Mangrove Warblers, Grinnell's Water-Thrushes, Belding's Rails, and Frazar's Green Herons, none of which, excepting the Water-Thrushes, were met with elsewhere by Mr. Frazar.

The shores or waters of this bay were also frequented by Large-billed Sparrows, Killdeer, Semipalmated and Wilson's Plovers, Gray Yellowlegs, Long-billed and Hudsonian Curlews, Reddish Egrets, Wood Ibises, Western Gulls, Caspian and Royal Terns, California Brown Pelicans, Man-o'-war Birds, Brandt's Cormorants, Pied-billed Grebes and other kinds of wading or water birds.

Triunfo. — On April 11 Mr. Frazar went to Triunfo, "a mining camp situated among the mountains, fifty miles south of La Paz, and at about the beginning of the oak level," although no trees of any kind were to be seen in the immediate neighborhood, all having been cut for use in the mine. The surrounding hills were excessively dry and barren, and even the arroyos had little vegetation, although they were inhabited by fair numbers of birds.

Within four miles of the camp, however, was a cañon, near the head of which water "bubbled from the ground" in sufficient quantity to form a brook of considerable size. For a distance of perhaps a quarter of a mile below its source this stream was filled with water cresses and half concealed by overhanging bushes, canes, or bulrushes, while the narrow strip of bottom land through which it flowed was under high cultivation. Further down the cañon it sank into the sand, coming to the surface again just above where a dam had been erected, and forming here a small but deep pond, in which a pair of Baldpates were seen on one occasion. Near the margin of this pool stood a number of "evergreen oaks," and a dozen or more "large northern oaks" were scattered along the lower slopes of the neighboring hills.

This little oasis was one of the most verdant and attractive spots which Mr. Frazar visited and, as would be expected, it proved to be alive with birds, of which Belding's Yellow-throat, the Beautiful Bunting, and Xantus's Hummingbird were among the most numerous and attractive.

Another place of especial interest was a "hill" lying at a distance of about ten miles from the mining camp, and having "an elevation of some 3,500 feet above sea level." From its summit could be seen "very plainly the Pacific Ocean and the coast line for thirty or forty miles. In the opposite direction was the Gulf of California, fifteen miles away and seemingly at our feet, for the slope on that side was very abrupt to the plain, which was not over three miles distant. To the north lay the entrance to La Paz harbor. Southward the view was interrupted by the San Simon range of mountains. The road lay up a ravine where there was considerable water (the drainage from one of the mines) as well as some scattered oaks, perhaps twenty in all, none over fifteen feet high. Here we found a number of birds, but on the hill tops there were very few."

Mr. Frazar made a second visit to Triunfo in early summer (June 10–July 2), and a third at the close of the year (December 4–11).

Pierce's Ranch. — Immediately after his second visit to Triunfo Mr. Frazar spent nearly a month (July 4–30) at Pierce's Ranch or San José del Rancho, as it is locally called. Beyond the brief statement that "it is about fifteen miles south-east of Triunfo, on the Gulf slope among the hills on the oak[1] level," Mr. Frazar's notes contain no description of this locality. It yielded few birds of especial interest, excepting a single specimen each of the St. Lucas Robin and Louisiana Tanager and a good series of Viosca's Pigeon.

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[1] An oak leaf obtained here by Mr. Frazar has been identified at the Gray Herbarium as that of *Quercus grisea* Liebmann.

Sierra de la Laguna. — The last few days of April, the whole of May, and the first week of June were spent on the Sierra de la Laguna. This is said to be the highest mountain on the Peninsula south of La Paz, although Mr. Frazar, who notes its altitude as about six thousand feet, thinks that several of the mountains which lie between it and Cape St. Lucas are but little inferior in elevation. He tells me that it is also called Rosario de la Laguna and Mount San Simon, but, if I understand him correctly, the latter name is more properly restricted to the highest of several peaks all of which, together with the broad-topped mountain mass on which they rest, and above which they rise only some two hundred or three hundred feet, are known collectively as the Sierra de la Laguna.

This and the neighboring mountains are invariably referred to in Mr. Belding's papers as the "Victoria Mountains," and the general range of which they form a part is marked "S. de la Victoria" on the map of Mexico compiled and drawn by Mr. Hendges and published (in 1900) under the auspices of the Bureau of the American Republics. Mr. Frazar assures me, however, that, so far as he was able to learn, the people of the Cape Region have no distinctive name for the range just mentioned, while he heard the term Victoria Mountains applied only to the group of mountains opposite Carmen Island which he visited during his trip up the Gulf of California.

The road by which Mr. Frazar approached the Sierra de la Laguna from Triunfo crosses a succession of cañons with their intersecting ridges, and hence is almost continually climbing or descending steep inclines. After passing Las Animas, a deserted ranch where the real ascent of the mountain begins, the trail becomes exceedingly difficult, and in places is almost impassable for pack animals. From the summit "the eastern, northern, and western sides of the mountain appear very abrupt," but towards the south the slope is more gradual. The distant view in this direction is interrupted by several mountains of considerable altitude. In the immediate foreground, at the base of the highest peak and scarce three hundred feet below it, lies a hollow completely surrounded by mountain-tops or ridges, whose inner sides, together with the depression towards which they trend, cover a total area of about four square miles. This is everywhere densely wooded with large oaks and pines,[1] the latter predominating on the lower ground and the former on the hillsides.

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[1] These trees have been identified at the Gray Herbarium, so far as could be determined from leaves alone, as *Pinus ayacahuite* Ehrenb., and *Quercus emoryi* Torr.

Near the head of the hollow rises a stream of clear, cool water, at present everywhere confined within its banks but formerly expanding, at a point just above where it escapes by a narrow cañon through the encircling hills, into a shallow lagoon from which the mountain derived its name. After descending through the ravine to lower levels and mingling its waters with those of other mountain brooks, this stream is said to sink into the ground, reappearing again a few miles above the town of San José, below which it empties into the sea.

In this attractive little subalpine valley Mr. Frazar spent, as I have already stated, upwards of six weeks, collecting assiduously and obtaining full series of most of the birds which had been previously reported from these mountains as well as several novelties which I have since described. Unfortunately he was too early for nests and eggs. Indeed only a very few of the birds had begun laying up to the date of his departure (June 9). He was assured by the deer hunters and cattle herders whom he met that the height of the breeding season is not reached here before July. He attempted to return at this time, but was prevented from doing so by a serious illness.

On November 27, however, he paid a second visit to the valley, remaining there up to December 4. The weather, during this period, was cold and damp and the mountain shrouded in mist. There were but few birds, and of these the greater number belonged to feeble-winged or habitually sedentary forms, such as Titmice, Nuthatches, Jays, etc., most of the summer species having evidently descended to the lowlands or migrated to warmer latitudes, to pass the winter. Nor had their places been taken by winter visitors from further north, for the Ferruginous Rough-legged Hawk was literally the only addition made, on this occasion, to the list of birds observed the previous spring.

As the latter will be fully treated in their appropriate places in my paper, it seems unnecessary to mention here any but the more characteristic or interesting species, such as the St. Lucas Robin, Grinda's Bush-Tit, Ashy Titmouse, St. Lucas Nuthatch, Western Martin, St. Lucas Swallow, Mountain Towhee, Baird's Junco, St. Lucas Flycatcher, Large-billed Wood Pewee, Xantus's Hummingbird, Narrow-fronted Woodpecker, Hoskins's Pygmy Owl, Dwarf Horned Owl, and Viosca's Pigeon, most of which were abundant and in the perfection of their nuptial plumage.

San José. — At the close of his third visit to Triunfo Mr. Frazar proceeded to San José del Cabo by a road which crosses the mountains to San Antonio and next passes through San Bartolo, beyond which it leads down an arroyo to the sea beach. Along this it continues for a distance of about ten miles and then turns inland, crossing a broad table-land to another arroyo, up which it runs to Santiago and thence across a second table-land to Miraflores, situated on still a third arroyo which the road follows for the remainder of the way to San José. Mr. Frazar spent the latter part of August, the entire months of September and October and the first twelve days of November, at this place, making daily excursions about its outskirts or to the neighboring sea-coast. His note-books and collections, as well as the published accounts relating to the experiences of Mr. Xantus, Mr. Belding, and Mr. Bryant, show that the locality is one of the most interesting and productive, ornithologically, of any in the Cape region of which we have definite knowledge.

San José is situated about one and one-half miles from the Gulf coast, on the edge of the arroyo, which, at this point, is upwards of two miles wide and almost perfectly level. Through it winds a good-sized brook, which rises among the mountains, and not far from their bases disappears beneath the ground, reappearing again some eight miles above the town and flowing past it over a broad, sandy bed on its way to the sea. Although at the time of Mr. Frazar's visit, there had been no rain for upwards of two years, this stream carried a considerable volume of water, much of which, however, was diverted from its natural channel to irrigate the bordering bottom lands. These are divided into gardens and yield good crops of sugar-cane, cotton, and oranges besides corn, beans, sweet potatoes[1] and such other vegetables as the inhabitants of the neighboring region require.

The banks of the stream, as well as those of the irrigating ditches are fringed in places with wild canes and dense bushes. "There are also a few trees, such as willows, palms, and a kind of poplar." About a mile below the town, the water forms numerous small pools filled with cat-o'-nine tails and floating vegetation, and just before reaching the ocean it spreads out into a shallow lagoon of about eight acres in extent which lies immediately behind the beach ridge. Its outlet was repeatedly closed, during Mr. Frazar's visit, by sand thrown up by the surf at high tide, but the water, after rising several feet above its normal level, would eventually burst through the temporary barrier and escape, sometimes by a new opening. From this point smooth sea-beaches backed by sand-dunes stretch as far as the eye can reach in both directions, to the southwest curving gently outward to form the rocky promontory known as San José del Cabo.

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[1] "Bananas do well at San José, but apples and potatoes they cannot raise, although the latter are grown successfully at Aqua Caliente." Bryant, Zoe, II. 1891, 195.

A distinction between this name and the shorter appellation San José, which, I believe, is the current and no doubt proper term for the village itself, was apparently made by Mr. Xantus in labeling his specimens, although there are reasons for believing that some of those which are marked "San José del Cabo" were really taken at or near the mouth of the river, and hence at some distance from the Cape itself. Mr. Belding employs both names in connections which indicate that he regarded them as synonymous. Mr. Bryant, in his Catalogue of the Birds of Lower California, invariably uses the longer title, applying it to all records relating to the village of San José, as well as to the neighboring sea-coast, without apparent regard to the form in which they originally appeared. No doubt, the fact that there are several San Josés, but only one San José del Cabo, in Lower California, prompted him to adopt this course, which, for the same reason, I have also followed, whenever it has seemed admissible, in the present paper.

It is not surprising that so rare a combination of attractive conditions as that just mentioned, — especially in a country so generally arid and barren as Lower California — should have given San José del Cabo an exceptionally rich and varied bird fauna. The smaller insectivorous or seed-eating birds find congenial shelter and abundance of food in the luxuriant vegetation with which the village and its immediate neighborhood are favored; reed-loving species, such as Marsh Wrens, Yellow-throats, Rails, and Gallinules, inhabit the pools lower down the river; the shallow lagoon at its mouth affords a perfect paradise for waders and waterfowl of many different varieties, while Plover, Sandpipers, Gulls, Terns, Cormorants, Pelicans, and even such ultra-typical marine birds as Petrels and Shearwaters, frequent the neighboring sandy beaches or at least pass over or near them on their flights up and down the coast.

SYSTEMATIC NOTICE OF THE BIRDS.

Colymbus nigricollis californicus (Heerm.).

American Eared Grebe.

Dytes nigricollis californicus Belding, Proc. U. S. Nat. Mus., V. 1883, 546 (Cape Region).
Colymbus nigricollis californicus Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 249 (Cape Region).

The American Eared Grebe is a common winter resident in the Gulf of California off La Paz as well as about the islands to the northward, where, during February and March, Mr. Frazar saw it frequently, often in large flocks and occasionally where the water was very deep. At San José del Cabo he met with it only once, on October 18, when a single bird was noted. Mr. Belding also mentions seeing it near La Paz. Mr. Bryant found it "common along the shores of Magdalena Bay, particularly at Magdalena Island. They were seen about the landing swimming in compact groups of from one to two dozen birds, the entire flock would dive almost simultaneously and appear again in a more scattered bunch a short distance away. Their tameness made them objects to be stoned by Mexican boys who occasionally killed and wounded some."

There is no evidence that the Eared Grebe breeds in any part of Lower California, although the southern limits of its known summer range lie not far to the northward, for it has been found nesting in California at Elizabeth Lake, Los Angeles county, and abundantly at Bear Valley Lake in the San Bernardino Mountains.[1] In winter it migrates as far south as Guatemala.

Colymbus dominicus brachypterus Chapman.

Short-winged Grebe.

Tachybaptes dominicus (not *Colymbus dominicus* Linnaeus) Belding, Proc. U. S Nat. Mus., VI. 1883, 351 (San José, Miraflores, and Santiago).
Colymbus dominicus (not of Linnaeus) Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 250 (San José, Miraflores, and Santiago).

Of the thirty-one specimens of this Grebe collected by Mr. Frazar at Santiago about one-half are adults, the remaining half being young of various ages from chicks still in their natal down to fully grown birds in fresh winter plumage. On comparing these skins with eight West Indian examples of *dominicus* (two from Jamaica, three from the Bahamas, and three from Cuba), I find that the characters by which Mr. Chapman has proposed to distinguish *brachypterus* from *dominicus* are very satisfactorily maintained. The males of both forms have considerably larger bills than the females, a fact which should be borne carefully in mind when birds from different localities are examined. The material before me furnishes, however, no male from Lower California with a bill as large as that of the smallest-billed female from the West Indies, and the difference in this respect between birds of the same sex from the two regions is very striking.

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[1] Grinnell, Pub. II. Pasadena Acad. Sci., 1898, 5.

This little Grebe was first reported from Lower California by Mr. Belding, who says that it was "very common at San José, Miraflores, and Santiago, in the winter of 1882–'83, but not recognized the previous winter." Mr. Frazar found it only at Santiago in a lagoon of about two hundred acres in extent, the greater part of which was filled with a rank growth of tule, there being but little open water. In this lagoon during the latter half of November the Short-winged Grebes were very common, upwards of a hundred being often seen by Mr. Frazar in the course of a single morning. Among the specimens obtained here are several young birds which must have been hatched in the lagoon. Indeed one (No. 18,270), taken November 15, is a mere chick, barely one-third grown and still wholly in the down.

Although this Grebe has been attributed to the "valley of the Colorado"[1] River it seems probable that the resident colony above referred to was derived from western Mexico, where the bird is abundant and widely distributed. It is not known to occur anywhere in the central or northern portion of Lower California.

Podilymbus podiceps (Linn.).

Pied-billed Grebe.

Podilymbus podiceps Belding, Proc. U. S. Nat. Mus., V. 1883, 546 (Cape Region).
Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 250 (Cape Region).

The Pied-billed Grebe is common in winter about the Bay of La Paz and its inlets. It was also found by Mr. Frazar in September and October at San José del Cabo, where it "arrived" on September 12. It haunts chiefly, if not exclusively, the salt or brackish bays, or creeks near the coast and appears to desert at least the southern portion of the peninsula during the breeding season. This is somewhat remarkable, for the Pied-billed Grebe is said to breed throughout the whole of Mexico and Central America as well as most of South America and there would seem to be no reason why it should not nest with the Short-winged Grebes in the lagoon at Santiago.

[1] Baird, Brewer, and Ridgway, Water Birds N. Amer., II. 1884, 439.

Gavia imber (GUNN.).

LOON.

Colymbus torquatus BELDING, Proc. U. S. Nat. Mus., VI. 1883, 352 (La Paz).
Urinator imber BRYANT, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 250 (La Paz).

Although the Loon is common in winter along the coast of California as far south as San Diego Bay the only authority for its occurrence in any part of Lower California is Mr. Belding, who has recorded seeing two specimens at La Paz on January 27, 1883. The bird must be a rather rare visitor to this locality, which probably represents about the southern limit of its winter wanderings on the Pacific coast.

Brachyramphus hypoleucus XANTUS.

XANTUS'S MURRELET.

Brachyrhamphus hypoleucus XANTUS, Proc. Acad. Nat. Sci. Phila., 1859, 299 (orig. descr.; type from Cape St. Lucas). BAIRD, *Ibid.*, 301 (Cape St. Lucas), 306 (crit.; Cape St. Lucas). COUES, *Ibid.*, 1868, 64–66 (crit.; Cape St. Lucas). ELLIOT, Illustr. New and Unfig. N. Amer. Birds, II. 1869, pl. 72 (descr. and figures type specimen from Cape St. Lucas). RIDGWAY, Proc. U. S. Nat. Mus., V. 1883, 534, footnote (Cape St. Lucas; San José).
Brachyramphus hypoleucus BAIRD, BREWER, and RIDGWAY, Water Birds N. Amer., II. 1884, 502 (iris "pale blue," XANTUS, MS.; Cape St. Lucas). BRYANT, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 250 (Cape Region).

This species was taken both at Cape St. Lucas and San José del Cabo by its discoverer, Mr. Xantus, in 1859, but rather curiously it does not seem to have been since observed near the southern extremity of Lower California, nor ever actually within the Gulf of California, where it is replaced by the closely-allied *B. craveri*, which appears to be strictly confined to the Gulf during the breeding season and practically so at all other times of the year. Mr. Anthony, who has found *B. hypoleucus* breeding on many of the islands off the Pacific Coast of Lower California north of Magdalena Bay, says that it "begins nesting in late January, though I have found fresh eggs as late as early April. Late in February they may be seen at sea in family parties consisting of the parents and one or two downy young, which are taken to the water the first night, I think, after they are hatched. The young stay in company with the adults until late in the year." He adds that among some seventy-five specimens of both sexes and all ages which he has taken between Santa Barbara Islands and Magdalena Bay only one has "suggested in any way the plumage known as *craveri*," while concerning the identity of this single exception he was evidently in some doubt.[1]

[1] Auk, XVII. 1900, 168, 169.

Off the coast of southern California Xantus's Murrelet is now known to occur more or less commonly at all seasons from San Diego to the Santa Barbara Islands, where it probably breeds. It sometimes ranges still further northward, for Mr. Loomis has reported[1] the capture of a single bird near Monterey on July 28, 1894, and I have seven specimens which were taken in the same locality by Mr. Alvin Seale in November and December, 1896, and January and February, 1897.

Brachyramphus craveri (Salvad.).

Craveri's Murrelet.

Uria craveri Salvadori, Atti Soc. Ital. Sci. Nat., VIII. 1865, 387–389 (orig. descr.; type from Gulf of California).

Brachyrhamphus craveri Coues, Proc. Acad. Nat. Sci. Phila., 1868, 66 (quotes orig. descr.; crit.). Coues and Streets, Bull. U. S. Nat. Mus., no. 7, 1877, 32, 33 (descr. eggs and habits; crit.; Isla Raza, Gulf of Calif.). Ridgway, Nom. N. Amer. Birds (Bull. U. S. Nat. Mus., no. 21[2]), 1881, 57, no. 758; Proc. U. S. Nat. Mus., V. 1883, 534, footnote (Cape St. Lucas).

[*Brachyrhamphus*] *craveri* Elliot, Illustr. New and Unfig. N. Amer. Birds, II. 1869, introd. (figures head and leg; quotes orig. descr.; crit.).

[*Brachyramphus*] *craveri* Gray, Hand-list, III. 1871, 100, no. 10,815.

[*Synthliborhamphus*] *wurmizusume* Coues, Key N. Amer. Birds, 1872, 344, part (Cape St. Lucas).

Synthliborhamphus wurmizusume Coues, Check List, 1873, 117, no. 628, part.

Brachyrhamphus craverii Coues, Check List, 2d ed., 1882, 132, no. 869.

Brachyramphus craverii Baird, Brewer, and Ridgway, Water Birds N. Amer., II. 1884, 502, 503 (descr.; crit.; figures head, bill, and leg; coast of Gulf of Calif.; Island of Natividad).

Brachyramphus craveri A. O. U., Check List, 1886, 81, no. 26. Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 251 (Cape St. Lucas; Natividad Island).

B.[*rachyrhamphus*] *craverii*? Coues, Key N. Amer. Birds, 4th ed., 1894, 814 (crit.; figures head and leg; Lower Calif.).

B.[*rachyrhamphus*] *craveri* Ridgway, Man. N. Amer. Birds, 2d ed., 1896, 15 (descr.; Cape St. Lucas).

Micruria craveri Ogilvie-Grant, Cat. Birds Brit. Mus., XXVI. 1898, 595 (descr.; near Cape St. Lucas). Anthony, Auk, XVII. 1900, 168, 169 (crit.).

Endomychura craveri Oberholser, Proc. Acad. Nat. Sci. Phila., 1899, 201 (new genus to include *B. hypoleucus* and *B. craveri*).

[*Micruria*] *craveri* Sharpe, Hand-list, I. 1899, 131.

Mr. Frazar collected no less than twenty-five specimens of *B. craveri*, of which fourteen were adults in more or less worn breeding plumage, and eleven young of various ages and both sexes. Of the adults eight were males, and six females. On comparing this fine series with seven specimens of *B. hypoleucus* taken at Monterey, California, in the winter of 1896–97 by Mr. Alvin Seale, I have become convinced that the doubts which certain writers have expressed[1] concerning the specific distinctness of *hypoleucus* and *craveri* are without foundation. The chief characters which appear to distinguish the two birds are as follows: —

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[1] Proc. Calif. Acad. Sci., 2d ser., V. 1895, 211, 212.

[2] Also printed in Proc. U. S. Nat. Mus., III. 1880, 163–246.

B. hypoleucus. Upper parts blackish slate often with a decided tinge of bluish ashy; lining of wings clear, immaculate white; inner webs of outer primaries nearly or quite pure white to within a short distance from the tips; many of the dark (bluish slate) colored feathers on sides of body conspicuously tipped with white.

B. craveri. Upper parts seal brown; lining of wings smoky gray or grayish white, many of the feathers with conspicuous spots or blotches of faded ashy brown; inner webs of all the primaries plain brown only a shade or two lighter than that of the outer webs and never approaching white save at the extreme bases of the feathers, which are sometimes brownish white; dark colored feathers on sides of body without light tipping.

The clear slaty tone of the upper parts in my examples of *hypoleucus* may be due to the fact that the birds were all taken at somewhat earlier dates in the winter than any of my specimens of *craveri*, but the other characters above mentioned are obviously not of a kind likely to be materially affected by mere seasonal differences of plumage.

The dissimilarity in respect to the color of the wing lining has been long known, only its constancy as well as its significance having been questioned. In the specimens before me it is absolutely constant, at least within certain limits. Most of my specimens of *craveri* have the under coverts conspicuously blotched and spotted with slaty or brownish on a smoky or ashy white ground, but in a few birds the lining of the wing is pure white and, at first glance, apparently almost immaculate. On close inspection, however, I find that all such specimens in my series have the white or whitish on most of the under wing coverts confined to the tips and edges of the feathers, their central portions being either slaty or brown. When the plumage is disarranged these dark markings become at once conspicuous.

The coloring of the wing lining varies greatly in young birds. The natal down which, at first, completely clothes the under surface of the wings is apparently always uniformly dark (reddish brown). Among the birds which have shed this down some have the under wing coverts dark slate or slaty brown relieved by only a few whitish markings on the tips of the feathers. With others of apparently similar age the under surface of the wings is not darker than in most of the adults. As a rule, however, the ground color of the under coverts appears to become lighter as the bird grows older, but the brown on the centers of the feathers evidently persists through life.

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[1] Dr. T. H. Streets and Mr. W. R. Ogilvie-Grant have suggested that *craveri* may be merely *hypoleucus* in full breeding plumage, while Mr. Anthony has "thought it possible that it may prove to be a plumage of the young carried through one or more moults."

In all my examples of *hypoleucus* the entire surface of the plumage which covers the under side of the wing is clear, immaculate white. Two birds have some concealed slaty or brownish on a very few of the longer coverts lying near the edge of the wing, but this is so restricted in extent and situated so near the bases of the feathers as to be scarcely noticeable, even when the plumage is violently ruffled ; nor can it, I think, be fairly regarded as representing any real approach to the conspicuous and practically universal dark mottling found on the under wing coverts of *B. craveri.*

B. hypoleucus, as represented in my collection, invariably has the whole inner web of the first primary pure white to within about an inch and one half of the extremity of the feather. Beyond this point the white gradually recedes from the shaft, terminating on the inner edge of the feather about three quarters of an inch from its tip. The shaft itself, with an exceedingly narrow space (a mere hair line) bordering it inwardly, is brownish white. With each succeeding quill the white retreats further and further from the tip of the feather, at the same time losing something of its purity. Beyond the sixth or at most the seventh primary it is rarely appreciable excepting at the extreme bases of the feathers. None of my examples of *craveri* show well defined white areas on any of the quills, although the brown of their primaries is often a shade or two lighter on the inner than on the outer web and sometimes changes insensibly into brownish white near the bases of the feathers.

Two of Mr. Frazar's specimens (♂ No. 18,288 and ♀ No. 18,294), both taken on the same date (March 1), are young, about one-half grown and still clothed, for the most part, in down. This, over the upper parts, is seal brown, slightly redder as well as paler than in adult birds and with fine transverse markings of whitish besprinkling the back and rump — but not the crown nor the wings. The throat is grayish, the abdomen white. On the jugulum and breast the down has been replaced by true feathers — those of the second stage of plumage and everywhere silky white save on the sides of the breast, where they are flecked with minute spots of blackish. The sides of the body with the under as well as the upper surfaces of the wings are covered with down of nearly the same shade of brown as that of the crown and back, but there are also a few budding wing coverts, as well as quills, the expanding tips of which are decidedly darker in color.

Other specimens in my series illustrate practically every stage through which the young pass in arriving at maturity. They show that the natal down is shed first on the breast, next on the throat and abdomen, next on the wings, next on the back, next on the chin, next on the center of the crown, next on the forehead, last of all on the occiput and sides of the crown. With the disappearance of the last shreds of down the bird completes what I suppose must be called its first winter plumage, although this in specimens which, like mine, were hatched and reared in January and February is really assumed in early spring. After perfecting this plumage the young can be distinguished from their parents only by their shorter and weaker bills, by the darker (nearly dead black) coloring of their upper parts and by the presence of numerous fine but rather conspicuous blackish spots or bars on the tips of the feathers of the sides of the breast and body.

According to Mr. Ridgway, Mr. Xantus took the present species at Cape St. Lucas in 1859, but it was not separated from *B. hypoleucus* until 1867. The type specimen of *craveri* is said[1] to have come from somewhere near the Isla Raza in the Gulf of California, where Dr. Streets found the species breeding in 1875. It appears to be mainly confined to the Gulf, but, according to Count Salvadori, has also occurred off the Pacific coast of Lower California, at the island of Natividad.

On March 1, 1887, while on his way to Carmen Island, Mr. Frazar found Craveri's Murrelets in considerable numbers near the island of San José, and on March 18 they were again met with off the northern end of Espiritu Santo Island. Three or four were usually seen together, each group consisting of a pair of old birds accompanied by a single young or of two old females and two young. Although none of the old females seemed to have more than one young each, all of those shot and examined showed *two* bare incubating spaces on the belly. Judging by the size of the young, the eggs from which they had been hatched must have been laid early in January and at some spot not far from where the birds were found, perhaps, as Mr. Frazar suggests in his notes, on a certain "small, round, high rock about an acre in extent opposite the island of San José and near the shore of the Peninsula."

The early date of breeding established by the capture of these young is a matter of surprise, for Dr. Streets obtained an adult female and her set of two eggs on Isla Raza (in the Gulf of California) in *April*, 1875. The eggs were "taken from a crevice of a rock at arm's length." They "resemble those of the tern, though rather elliptical-ovoid in shape. They differ from each other decidedly in the ground-color as well as in the markings. The darkest one is brownish-drab, with nearly half of the surface (on the larger end) heavily and confluently blotched with reddish-brown and dark brown, with a few neutral-tint shell-markings interspersed; the rest of the egg is sparsely sprinkled with smaller and more distinct markings of the same color. The ground of the other egg is clay-colored, or very pale stone-gray, with markings of the same color as before, but less heavy, more distinct, and smaller. There is the same aggregation of spots about the larger end, but not so fully carried out, and the rest of the surface is more thickly and uniformly flecked than the same portion is on the other egg. The darker egg measured 2.05 by 1.40; the other 1.95 by 1.35. The eggs of the species, as far as we are aware, have not before been described."[2]

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[1] Salvadori, *Loc. cit.*

[2] Bull. U. S. Nat. Mus., no. 7, 1877, 32.

Larus occidentalis Aud.

Western Gull.

Larus occidentalis Belding, Proc. U. S. Nat. Mus., V. 1883, 545 (Cape Region), 549 (San José). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 251 (Cape Region).

The Western Gull is resident along the Gulf coast of the Peninsula and is very common in places, especially in the Bay of La Paz, in winter. Mr. Frazar found a breeding colony of about twenty-five pairs on a small rocky island a little to the westward of Carmen Island. Most of the nests were only just begun, and but two contained eggs, one set, however, comprising the full complement of three. This was on March 13, a date about two months earlier than that at which the first eggs are usually taken on the Farallon Islands near San Francisco. The next day another breeding ground was discovered on the northern end of the island of Montserrat. Here some fifty pairs had congregated. Few of their nests were finished and only eight contained eggs, the number in each set varying from one to three. At both of the places just mentioned, the nests, which were made of seaweed, were built at the foot of the cliffs just above high-water mark and often in nooks or crevices.

Mr. Bryant notes the Western Gull as "tolerably common at Magdalena Bay in winter, and northward along the western coast," adding that it is "said to breed upon the Todos Santos Islands off Ensenada." Mr. Goss states [1] that a few nest on San Pedro Martir Isle.

The general range of this species includes practically the entire Pacific coast of North America.

Larus californicus Lawr.

California Gull.

Larus californicus Belding, Proc. U. S. Nat. Mus., V. 1883, 549 (San José). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 251 (San José del Cabo).

Mr. Frazar notes this Gull as "common in winter at La Paz," and also met with between Loreto and Carmen Island on March 13, but his collection contains no specimens. Mr. Belding records it as "moderately common," and mentions seeing it at San José del Cabo as late as May 17. There is no probability, however, that it breeds anywhere in or near Lower California. Mr. Bryant "obtained immature birds at Magdalena Bay in the winter," but does not mention finding the species at any other locality.

The California Gull has occurred in winter on the western coast of Mexico as far southward as the Rio de Coahuayana, Colima. It is also a common winter bird on the coast of California, but it breeds exclusively in the interior. Mr. S. W. Denton tells me that in 1880 he found a large colony nesting on a volcanic island in Mono Lake (eastern California), which is perhaps the most southern locality where the eggs have been taken.

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[1] Auk, V. 1888, 241.

Larus delawarensis Ord.

Ring-billed Gull.

Larus delawarensis Belding, Proc. U. S. Nat. Mus., V. 1883, 545 (Cape Region). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 251 (Cape Region).

Mr. Belding includes the Ring-billed Gull in a list of birds found in the Cape Region[1] between December 15, 1881, and May 17, 1882, but he says nothing whatever about its comparative scarcity or abundance. Mr. Frazar did not meet with, or at least certainly identify, the species, nor is it mentioned by Xantus, Streets, or Townsend. According to Mr. Bryant it has been seen in winter at San Quentin Bay by Mr. Anthony. On the western coast of Mexico, nearly opposite Cape St. Lucas, Colonel Grayson found it "common during the winter months in the neighborhood of Mazatlan."[2]

Mr. H. W. Henshaw writes me that he has seen a few immature birds off San Buenaventura, California, during the month of November, and Mr. Grinnell characterizes the species as tolerably common along the coast of Los Angeles county in mid-winter, while at the latter season it has been found in small numbers at Monterey by Mr. Loomis.

The Ring-billed Gull breeds as far southward as southeastern Oregon, according to Captain Bendire.[3]

Larus heermanni Cass.

Heermann's Gull.

Blasipus heermanni Baird, Proc. Acad. Nat. Sci. Phila., 1859, 301, 306 (Cape St. Lucas).
Larus heermanni Belding, Proc. U. S. Nat. Mus., V. 1883, 545 (Cape Region).

Young specimens of this Gull were collected at Cape St. Lucas by Mr. Xantus in 1859, and Mr. Belding gives the species without comment in his list of birds observed at La Paz in the winter of 1881–82. Mr. Frazar's collection contains three skins obtained on March 13, near Carmen Island. His notes include only one reference to the bird, a mere incidental mention of a specimen which he saw at San José del Cabo on September 6.

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[1] Mr. Ridgway tells me that there is a specimen (♀ adult, No. 86,392) in the National Museum which was taken by Mr. Belding at La Paz, on February 15, 1882.

[2] Baird, Brewer, and Ridgway, Water Birds N. Amer., II. 1884, 246.

[3] Proc. Bost. Soc. Nat. Hist., XIX. 1877, 148.

Mr. Bryant says that Heermann's Gull was "the most common species of *Laridæ* met with at Magdalena Bay, nearly all being in immature plumage. They attend in large numbers the flocks of pelicans and cormorants when fishing. They occur commonly along both coasts [of the Peninsula], breeding on the islands."

According to Dr. Streets: —[1]

> "Isla Raza is the particular breeding-place of these gulls in the gulf. It is a small, low island, about three-quarters of a mile long and half a mile wide. At the time of our visit (April), immense numbers of the birds were congregated there, preparatory to laying their eggs, which, however, they had not begun to deposit. We may safely say, without exaggeration, that there was a bird on every square foot of the ground, and others were continually hovering about overhead. Their incessant noise deadened all other sounds, and so intent were they in their all-absorbing duties of reproduction, that they seemed entirely unconscious of our presence amongst them. The formation of the island is a black volcanic rock, entirely destitute of vegetation. Through the long series of years during which these birds have made it a breeding-place, there has been going on a chemical reaction between the acids of their excrement and the bases of the rock, which has resulted in the formation of a new substance, composed largely of a tri-basic phosphate. . . . The altered rock being a softer material than the original is easily pulverized and worn off by the constant attrition of the birds' feet during their breeding-season."

Larus atricilla Linn.

Laughing Gull.

Mr. Frazar appears to be the only collector who has found the Laughing Gull in Lower California. He took a young female in autumnal plumage at San José del Cabo on September 6, and on November 9, at the same place, saw another bird which he thought belonged to the same species.

L. atricilla is said to inhabit the Pacific coast of Central America, and it has occurred near Mazatlan on the western coast of Mexico,[2] but it is not known to visit California. It seems probable, therefore, that Mr. Frazar's birds were stragglers from Mexico, rather than migrants from the north.

Larus philadelphia (Ord).

Bonaparte's Gull.

Larus philadelphiae Belding, Proc. U. S. Nat. Mus., V. 1883, 545 (Cape Region).

Larus philadelphia Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 251 (Cape Region). Townsend, Proc. U. S. Nat. Mus., XIII. 1890, 137 (La Paz).

Mr. Frazar did not meet with this Gull, but it is included in Mr. Belding's list of birds observed in the Cape Region between December 15, 1881, and May 17,

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[1] Bull. U. S. Nat. Mus., no. 7, 1877, 26.

[2] Baird, Brewer, and Ridgway, Water Birds N. Amer., II. 1884, 257.

1882, and a specimen was also taken by Mr. Townsend at La Paz on March 14, 1889. Mr. Bryant says nothing about its occurrence further to the northward along the Peninsula. It is "common at Puget Sound at all seasons of the year," according to Dr. Cooper, but appears "about San Francisco only from September to May," and does "not seem to migrate as far south as San Diego, although Dr. Cooper met with some at San Pedro, late in May, in their immature plumage."[1]

Mr. Grinnell considers[2] it only an "occasional winter visitant along the coast" of Los Angeles county, but at Monterey Mr. Loomis has found it in considerable numbers early in November and about the middle of May, although he has met with but a single individual in mid-winter.[3] These facts point to the conclusion that the Cape Region lies somewhat to the southward of the usual winter range of this species on the Pacific coast. It breeds chiefly, if not exclusively, north of the northern boundary of the United States.

Sterna caspia Pall.

Caspian Tern.

The only specimen obtained by Mr. Frazar is an adult female in winter plumage, shot at La Paz on January 25. It has the entire cap black, with all the feathers edged and tipped with white. The inner web of the first primary shows a broad space of white along its inner border much as in *S. maxima*, but the white is less pure, and the slaty next the shaft is paler and grayer, the contrast between the two colors being less striking than in *maxima*, although their line of demarcation is clearly defined. The next two primaries also possess some white.

S. caspia is described[4] as having the inner webs of the primaries "uniform slate or dark hoary gray," but this is by no means invariably the case, for in several of my specimens from the Atlantic coast of the United States the inner portion of the inner web of at least the first primary is appreciably lighter than the part next the shaft, although none of them show any close approach in this respect to the Lower California example. The latter measures: wing, 16.75; tail, 5.60; tarsus, 1.65; length of bill from nostril, 1.74; depth of bill at nostril, .73. In addition to its other peculiarities this specimen has an unusually white mantle.

This Tern, previously unknown from any part of Lower California, is noted by Mr. Frazar as "rare at La Paz in January, and not seen during my trip up the coast in March." The species has occurred in California, but is apparently rather rare everywhere on the Pacific coast of North America, where the southern limits of its winter range are not, as yet, definitely known.

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[1] Baird, Brewer, and Ridgway, Water Birds N. Amer., II. 1884, 262.

[2] Pub. II. Pasadena Acad. Sci., 1898, 7.

[3] Proc. Calif. Acad. Sci., 2d ser., VI. 1896, 24, 25; 3d ser., II. 1900, 296, 297, 318, 350, 358.

[4] Baird, Brewer, and Ridgway, Water Birds N. Amer., II. 1884, 281.

Sterna maxima Bodd.

Royal Tern.

Thalasseus regius Belding, Proc. U. S. Nat. Mus., V. 1883, 545 (Cape Region), 549 (San José).
Sterna maxima Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 251 (Cape Region).

Mr. Frazar found the Royal Tern in January at La Paz, where it was rare, but somewhat more numerously represented than the Caspian. He did not meet with it on his trip to Carmen Island, but saw a few at San José del Cabo in September and October. At the latter place it was "common" on May 17, 1882, according to Mr. Belding. It is not mentioned either by Dr. Streets or Mr. Townsend, and apparently was not observed by Mr. Xantus. Mr. Bryant records it from the northwest coast in winter on the authority of Mr. Anthony, and from Cerros Island in April and May on that of Mr. Belding. It is a common bird on the coast of California, and is said to breed on the island of San Miguel. It ranges southward on the Pacific coast to Peru.

The collection contains two specimens — an adult female in nearly full nuptial plumage, shot at La Paz, on January 25, and a young or at least immature bird taken at San José del Cabo, on September 5.

Sterna elegans Gamb.

Elegant Tern.

Sterna elegans Townsend, Proc. U. S. Nat. Mus., XIII. 1890, 137 (La Paz.).

The only record that I can find of the occurrence of the Elegant Tern in the Cape Region is that by Mr. Townsend of a specimen shot at La Paz on March 14, 1889, but Mr. Bryant found numbers "around Magdalena Bay in 1888," and "obtained five adult plumaged birds"[1] at the same place the following season. The species occasionally wanders still further northward, for Dr. Cooper has reported its capture in San Francisco Bay.[2] There can be little doubt that it regularly frequents both coasts of the Gulf of California, and it probably breeds there, also, for there is an egg in the National Museum from Guaymas.

The Elegant Tern is believed to be confined to the Pacific coast of America, and is known to range as far south as Chili.

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[1] Proc. Calif. Acad. Sci., 2d ser., II. 1889, 252.

[2] Proc. Calif. Acad. Sci., IV. 1868, 10.

Sterna forsteri Nutt.

Forster's Tern.

Sterna forsteri Belding, Proc. U. S. Nat. Mus., V. 1883, 546 (Cape Region). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 252 (Cape Region).

This Tern is mentioned without comment in Mr. Belding's list of birds found in the Cape Region between December 15, 1881, and May 17, 1882. Mr. Frazar met with it only at San José del Cabo where he shot three specimens, one on September 29, the other two on the following day. Six in all were seen on these dates, and none either before or afterwards.

All three of the specimens secured are in winter plumage. One is perhaps an old bird. The other two have some of the feathers of the mantle tipped with faded brown and are probably young. In one of the latter the outer webs of the outer pair of tail feathers are uniform dark slaty for a terminal space of more than an inch in length, but the extreme tips of these feathers are white in both webs.

According to Mr. Bryant, Forster's Tern has been observed on the northwest coast of the Peninsula by Mr. Anthony. It occurs in various parts of California, and Dr. Heermann has found it breeding in the valley of the Sacramento River. On the whole, however, it appears to be much less numerous near the Pacific coast than in the interior of North America. It migrates as far south "as Guatemala, on both the Pacific and Atlantic side, and even to the latitude of Pernambuco, Brazil." [1]

Sterna hirundo Linn.

Common Tern. Wilson's Tern.

Mr. Frazar is apparently entitled to the credit of first detecting the Common Tern in Lower California. He observed it only at San José del Cabo, where six specimens, all young birds, were taken along the beach at various dates between the 5th and 30th of September. This species, although one of the most cosmopolitan of its tribe, "is not common — if indeed it breeds at all — on the Pacific coast; but throughout California — according to Dr. Heermann — it is very abundant along the rivers in the interior during the summer, retiring southward in the winter. Dr. Cooper never met with it on the sea-coast of California, . . . nor did he see it on the Columbia River." [2]

The accuracy of the statement attributed to Dr. Heermann in the passage above quoted is open to grave suspicion, for none of the field observers who have been so numerous and active in California during the past decade have found Wilson's Tern abundant or even common. Indeed, it appears to be doubtful if there are any really authentic records of its occurrence, especially in the interior of the state.

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[1] Saunders, Proc. Zool. Soc. Lond., 1876, 651.

[2] Baird, Brewer, and Ridgway, Water Birds N. Amer., II. 1884, 297.

Sterna antillarum (Less.).

LEAST TERN.

The Least Tern also, if I am not mistaken, is now reported for the first time from Lower California, where, however, its presence is not surprising since it breeds abundantly on the coast of California as far northward, at least, as Los Angeles county, while it ranges southward along the western coast of Central America.

Mr. Frazar found it only at San José del Cabo, where, between September 6 and 12, six specimens, including both young and old birds in autumn plumage, were taken. He speaks of it in his notes as "not common, but yet more numerous than any of the other Terns observed at San José."

Hydrochelidon nigra surinamensis (Gmel.).

BLACK TERN.

This is the fourth species of Tern which Mr. Frazar has added to the fauna of Lower California. Like the other three, it was seen only at San José del Cabo, where it was "rare." A specimen was taken on the 6th and another on the 17th of September.

The Black Tern was found by Mr. Grayson "at Mazatlan, where it makes its appearance in September and October, and where it remains through the winter months." Dr. Cooper states that it "migrates through the interior valleys of California, and that some probably breed about the marshes within the State, especially in the mountains, as he met with it on the head-waters of the Mohave River as late as the 7th of June."[1] Hence it is possible that Lower California lies nearly in the direct path of one of its regular lines of migration.

Puffinus opisthomelas Coues.

BLACK-VENTED SHEARWATER.

Puffinus opisthomelas Coues, Proc. Acad. Nat. Sci. Phila., 1864, 139–141 (orig. descr.; types from Cape St. Lucas). Elliot, Illustr. New and Unfig. N. Amer. Birds, II. 1869, introd. (descr.; figures head of specimen from Cape St. Lucas).

P.[uffinus] opisthomelas Coues, *Loc. cit.*, 144 (descr.; Cape St. Lucas).

Puffinus gavia (not *Procellaria gavia* Forster) Bryant, Proc. Calif., Acad. Sci., 2d ser., II. 1889, 87 (Cape St. Lucas).

"A large number of medium-sized, white-breasted and dark-backed Shearwaters," seen by Mr. Frazar between the islands of Carmen and Montserrat on March 6, and a few off the northern end of Espiritu Santo Island on March 18, probably belonged to this species, but they were so shy and restless that no specimens could be obtained. Dr. Coues, in connection with his original description of *P. opisthomelas*, states that " two fine examples are contained in the Smithsonian Museum, both collected by Mr. John Xantus at Cape St. Lucas, Lower California (Smiths. Catalogue, Nos. 16,990, 16,991)," but Mr. Ridgway writes me that the only specimens now in the National collection from Lower California are "as follows: No. 16,990, ♀ ad., Cape St. Lucas, '1859–'61' (no further data); type. — No. 31,964, San Nicolas; J. G. Cooper, no date."

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[1] Baird, Brewer, and Ridgway, Water Birds N. Amer. II. 1884, 321.

Until recently the Black-vented Shearwater has been considered a very rare bird, and almost nothing has been definitely known about its habits or distribution, but during the past decade Mr. Loomis[1] has found a Puffinus which he refers to *opisthomelas* (although "all the specimens obtained differ considerably from the type") off the coast of California, near Monterey, where he has noted its appearance sparingly in August, abundantly in September, by "thousands" in December and early January. As most of the birds seen in December and January were flying southward, Mr. Loomis inferred very naturally that they were "migrating to a breeding habitat further south," and that "while their destination may have been north of the equator, it seems highly probable that they did not stop short of the Southern Hemisphere." Mr. Anthony, however, has since reported[2] that in May, 1892, he found *Puffinus opisthomelas* in large numbers, and evidently breeding, on Guadaloupe Island, only "about 220 miles south of San Diego, and about 65 miles from the nearest mainland, Punta Baja, on the Peninsula" of Lower California. The nests, being placed either under huge blocks of lava, or in rocky crevices, often in the vertical walls of high cliffs fronting the water, were all inaccessible, but several of the birds were caught in steel traps placed at the entrances to their holes and dissection of these and other specimens convinced Mr. Anthony that they "had at that time well grown young." In the interesting article from which the above quotations are taken, Mr. Anthony says that "Major Chas. E. Bendire writes me that there are four eggs of this species in the National Museum collection, collected in 1873 on Santa Barbara Island by Capt. C. M. Scammon." He also states that he has found *Puffinus opisthomelas* "not uncommon on several occasions off the Columbia River during the summer months and in November and January," and that "on one occasion I met with a flock on the coast of Lower California that I estimated contained not less than 50,000" birds. Still more recently Mr. Anthony has published[3] the following additional and highly interesting facts relating to the breeding distribution and habits of the Black-vented Shearwater: —

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[1] Proc. Calif. Acad. Sci., 2d ser., V. 1895, 216; VI. 1896, 2, 27; 3d ser., II. 1900, 320.

[2] Auk, XIII. 1896, 223–228.

[3] Auk, XVII. 1900, 248, 249.

"On the San Benito Islands, lying between Guadaloupe and Cerros Islands, I have also found a few *P. opisthomelas* nesting. So far as I have been able to discover, there are no burrows on these islands, all the nests being in small caves, which are nearly filled with deposits of guano left by untold generations of *Puffinus*. The caves are all small and the nests inaccessible, but I think that each cave was inhabited by several pairs of birds, judging by the outcry and warning hisses that greeted my approach to the entrance.

"About thirty-five miles south of San Benito Islands lies Natividad Island, a lower and more sandy island than those previously mentioned — a condition which seems to suit the requirements of the Black-vented Shearwaters to a nicety, for here are found thousands of them, nesting the full length of the island, some three miles in extent. With the exception of a few rocky slopes and ridges the entire island may be said to be one almost continuous colony. This island I first visited in August, 1896. The size of the burrows at once attracted my attention, and a closer examination revealed the unmistakable tracks of a *Puffinus*. Though the footprints were abundant and fresh, proving that the burrows were still visited at night, all of those examined were unoccupied. I again called at Natividad April 10, 1897, and found the breeding season at its height, each burrow containing either a pair of Shearwaters or one Shearwater and a fresh egg. In no case, I think, did I find an egg in a burrow with two birds. The burrows were usually about ten feet in length, seldom if ever straight, but with one or two sudden turns to the right or left, the nest sometimes being but two feet from the entrance though at the end of a ten foot burrow. Few of the nests were over eighteen inches below the surface, the burrows being for the most part nearly horizontal, and the loose nature of the soil made walking anything but a pleasure, as one constantly broke through into tunnels, the exact location of which it was impossible to determine. . . .

"There was little attempt at nest-building, the eggs for the most part being laid in a depression in the sand at the end of the burrow. In a few cases a number of small twigs and sticks had been placed in the hollow forming a very crude nest. Before the egg is deposited the burrow is occupied by both birds, and I have found them on the nest at least a month before any eggs were laid. Just how early they take to the burrows I am unable to say, not having visited the nesting colony earlier than the first week in March, when all the burrows were occupied.

"I have never heard any love notes from this species when in the burrows. Their outcry at night, however, when they emerge from their nests and fly about over the island, is something unique in my experience. The noise is a series of choking cries coupled with a hissing, like escaping steam, the same that I have at times heard them utter when disturbed in their burrows."

Puffinus auricularis C. H. TOWNSEND.

TOWNSEND'S SHEARWATER.

Puffinus auricularis ANTHONY, Auk, XV. 1898, 38 (Cape St. Lucas); XVII. 1900, 249-252 (Cape St. Lucas; nesting habits on San Benedicto Island).

This species, discovered[1] at Clarion Island by Mr. Townsend in March, 1889, was found in the waters of the Cape Region some eight years later by

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[1] Proc. U. S. Nat. Mus., XIII. 1890, 133, 134.

Mr. Anthony, who has given us the following brief but definite account of its breeding habits: —

"About Cape St. Lucas Townsend's Shearwater (*Puffinus auricularis*) is rather common, and though perfectly distinct specifically it is quite closely related to *P. opisthomelas* and has a similar breeding season. On San Benedicto Island I found a few nesting the last week in May. At this date most of the young were but a few days old, covered with sooty down above, and paler-grayish below. With the smaller young I often found one of the parents, but they were as frequently alone. The burrows were all confined to the higher parts of the island — about 500 feet above the sea, where they were dug among the bunches of thick, tangled grass, and were well scattered, a dozen or so being a large colony. The burrows were not so deep or long as were those of *P. opisthomelas* on Natividad, averaging about five feet in length. On Clarion Island this species was again found in a similar location, all of the burrows being confined to a thick growth of grass, on the high parts of the island.

"The Clarion colonies were more extensive, each suitable patch of grass being well populated. Few birds were seen at sea during the daytime and at night, those that visited the nests must have been much more silent than is the Black-vented Shearwater, in the vicinity of its colonies, for I do not remember hearing any notes that I could attribute to *P. auricularis* though one or two of those that were dragged from their nests gave vent to their displeasure in notes similar to those of *P. opisthomelas*."

Puffinus griseus (Gmel.).

Dark-bodied Shearwater.

Nectris amaurosoma Coues, Proc. Acad. Nat. Sci. Phila., 1864, 124, 125 (orig. descr.; type from Cape St. Lucas; crit.).

N.[ectris] amaurosoma Coues, *Loc. cit.*, 143 (descr.).

Puffinus griseus Ridgway, Proc. U. S. Nat. Mus., V. 1883, 534, footnote (Cape St. Lucas). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 252 (Cape St. Lucas).

The specimen[1] obtained by Mr. Xantus at Cape St. Lucas on August 18, 1860, remains the only example known to have been taken in the waters of the Cape Region, where, however, the bird must occur commonly, at least during migration, for Mr. Loomis has ascertained[2] that it is a regular and at times abundant visitor to the coast of California in the neighborhood of Monterey, from June to December.

It is believed to breed only in the Southern Hemisphere, where in the neighborhood of Stewart's Island and along the adjacent coast of New Zealand "it burrows in peaty ground a horizontal hole, from three to four feet deep, and turning slightly to the right or left. At the end of this hole it forms a rude nest of twigs and dead leaves. Only one egg is laid, and the male is said to assist in incubation; and the parent birds are very savage while on the nest, biting and scratching those who molest them. The old birds roost on the shore, and the noise they make during the whole night is described as being something absolutely frightful."[1]

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[1] Type of *Nectris amaurosoma* Coues.

[2] Proc. Calif. Acad. Sci., 2d ser., V. 1895, 217; VI. 1896, 27, 28; 3d ser., II. 1900, 320.

Puffinus cuneatus Salvin.

Wedge-tailed Shearwater.

Puffinus cuneatus Anthony, Auk, XV. 1898, 38, 39 (Cape St. Lucas); XVII. 1900, 250–252, pl. 8 (Cape St. Lucas; nesting habits on San Benedicto Island, with figure of nesting site).

This Shearwater, previously "known only from the Bonin Islands south of Japan, Krusenstern Island, and the Hawaiian Islands," was also added to the fauna of Lower California by Mr. Anthony, who states that

> "About Cape St. Lucas, and between that point and the Revillagigedo Islands, the Wedge-tailed Shearwater (*Puffinus cuneatus*) is found in abundance in May and June. It probably may occur at other seasons, but as I have not visited the region of the Cape during other seasons I can give no assurance of its doing so. This species is of exceptional interest, as it belongs to a group of Shearwaters new to the North American fauna, and of which little is known. I was so fortunate as to discover a large colony nesting on San Benedicto Island, from which was obtained a fine series of skins with all of the intergrades between the white-bellied phase of '*cuneatus*' and the dusky form described by L. Stejneger from the Sandwich Islands as *knudseni*.
>
> "On first landing on San Benedicto, the first of May, I heard a low murmuring noise which seemed to come from the opposite side of the island. Thinking it might come from a rookery of seals, I started out to investigate, but soon found that I was getting no nearer the source of the noise, which possessed a ventriloquial power difficult to locate. I soon, however, found myself surrounded by large burrows which fairly honeycombed the entire south end of the island, which was so completely undermined that one constantly broke through into burrows, frequently sinking to the hips in ground that had every appearance of being solid. . . .
>
> "From many of the holes came moans and sobs in soft low tones, inexpressively sad and weird, — the love notes of *Puffinus cuneatus*.
>
> "A number of the burrows were opened, and from each were taken two birds, which fought and bit most savagely on being dragged to the light. By far the greater number were in dark plumage, but many showed lighter underparts, and in some cases a perfectly typical '*cuneatus*,' with pure white underparts, was found in the same burrow with a dark '*knudseni*.'
>
> "At this date the burrows were about four to five feet in length, most of them running in a nearly horizontal direction along the sides of the steep narrow ravines that everywhere cut this end of the island.

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[1] Baird, Brewer, and Ridgway, Water Birds N. Amer., II. 1884, 392.

"The soil is chiefly of fine pumice, in some places soft and easily excavated, but in others so hard as to require the use of a pick in opening the burrows. In most of the excavations was a rude attempt at nest building, consisting of a few sprigs of green grass and other vegetation which grew about the colony, and on this meagre platform were both birds, but no eggs. Nor did the condition of the birds indicate that the actual nesting season was at hand. About sunset the birds from the island began to seek the water, meeting a similar tide moving in from the sea. They mostly centred about the south end of the island, which soon presented the appearance of a vast beehive. Thousands upon thousands of Shearwaters were circling about with easy flight much more airy and graceful than that of any Shearwater with which I am familiar; especially was the difference accentuated when an occasional *auricularis* with typical Shearwater flight, skimmed through the throng. The greater part of those birds which came from the higher parts of the island descended at an angle of about 45°, with wings set until near the water, when they sailed off over the waves until lost to view, while others descending in a spiral course joined their fellows in circling about the water at the foot of the cliffs. There was little, if any, outcry, though the sobbing notes were often heard from the birds on shore. . . .

"Thinking I would find eggs, I returned to San Benedicto from Socorro Island two weeks later, but was disappointed. Many of the burrows were empty, and all had been extended two feet or more in length, and the nest of green plants moved back to the end. As before, when birds were found there were usually two."

Halocyptena microsoma Coues.

Least Petrel.

Halocyptena microsoma Coues, Proc. Acad. Nat. Sci. Phila., 1864, 79 (orig. descr.; type from San José del Cabo). Elliot, Illustr. New and Unfig. N. Amer. Birds, II. 1869, pl. 61 (descr. and figures type specimen from San José del Cabo). Ridgway, Proc. U. S. Nat. Mus., V. 1883, 534, footnote (San José del Cabo); VI. 1883, 158, footnote (crit.; s. Lower Calif.). Baird, Brewer, and Ridgway, Water Birds N. Amer., II. 1884, 402 (figures head, leg, and tail; near San José del Cabo). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 252 (San José del Cabo).

The type of this peculiar little species, an adult female taken by Mr. Xantus in May, 1861, near San José del Cabo, remained unique until March, 1888, when a second example flew on board the United States Fish Commission Steamer "Albatross" in Panama Bay, and was secured by Mr. Townsend.[1] Although the Xantus specimen appears to be the only one which has been thus far taken in the immediate neighborhood of Cape St. Lucas, the bird must occur there more or less regularly and commonly at times, for Mr. Anthony states that[2]

"In early June I have found the Least Petrel migrating along the coast of Lower California in company with the Socorro and Black Petrels, and in late July have found them nesting on the small rocky San Benito Island, fifty miles off the coast of the peninsula. So far I have never found the Least Petrel nesting in burrows. They have always been taken from the crevices in rocky ledges or among the loose stones. The pearly white egg is laid on the bare rock. Usually several are found within a few feet if desirable crevices are numerous. Young were taken as late as September 7 or 8 that were but a few days old. They were like the young of the three species of *Oceanodroma* I have mentioned, except for size. All are covered with sooty or slaty black down, through which the feathers appear when the bird is nearly or quite fully grown."

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[1] Proc. U. S. Nat. Mus., XIII. 1890, 141.

[2] Auk, XV. 1898, 142.

The passage just quoted contains practically all that is known at present respecting the breeding habits, as well as the general distribution, of the Least Petrel. An egg in my collection, taken by Mr. Anthony at San Benito Island, Lower California, July 26, 1896, is dead white without gloss or obvious markings. It is ovate in shape, and measures 1.03 × .74.

Oceanodroma melania (Bonap.).

Black Petrel.

Thalassidroma melania Baird, Proc. Acad. Nat. Sci. Phila., 1859, 301, 306 (Cape St. Lucas).

Cymochorea melania Coues ex Bonap., *Ibid.*, 1864, 76, 77 (descr. Cape St. Lucas specimen; crit.). Elliot, Illustr. New and Unfig. N. Amer. Birds, II. 1869, pl. 61 (descr. and figures specimen from Cape St. Lucas).

Cymochorea melaena Ridgway, Proc. U. S. Nat. Mus., V. 1883, 534, footnote (Cape St. Lucas).

Oceanodroma melania Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 253 (Cape Region).

Oceanodroma townsendi Ridgway, Proc. U. S. Nat. Mus., XVI. 1893, 687, 688 (orig. descr.; type from Cape St. Lucas).

Without doubt the Black Petrel, also, is a regular visitor to the waters immediately about Cape St. Lucas, although the specimen obtained there by Mr. Xantus over forty years ago is, I believe, the only one known to have been taken in that immediate neighborhood. In 1889, however, additional examples were collected near Guaymas by Mr. Townsend, and during the past fifteen years Mr. Anthony has apparently met with many others at various points to the northward of the Cape along both coasts of the Peninsula as well as, on one occasion, only about forty miles to the westward of San Diego, California.[1] From what the observer last-named has put on record it may be inferred that the bird is of regular and by no means uncommon occurrence, especially off the Pacific coast of Lower California. According to Professor Baird a specimen was obtained near San Francisco by Mr. Gruber at some time previous to 1859, and Dr. Cooper includes the species in a list of birds which he and others have met with at the Santa Barbara Islands,[1] where it was also seen by Mr. Grinnell in "the spring of '97."[2]

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[1] Auk, XI. 1894, 321, 322.

On July 10, 1896, Mr. Anthony found some Black and Socorro Petrels breeding together on one of the Coronado Islands (in the Gulf of California), but although the two fresh eggs (taken with the parent birds) of the former species which he obtained on this occasion were new to science, his description of them is limited to the remark that, like all those which he has "subsequently handled," they "were unmarked." His account[3] of this colony is so involved and so obscurely worded as to leave the reader in doubt as to which of the two species just mentioned many of the passages relate. Apparently only a few of the birds were positively identified, owing partly to their nocturnal habits, partly to the fact that most of their nests were in holes "under very large boulders or in cracks in the ledges," where it was impossible to get at them. Mr. Anthony states definitely, however, that the Black Petrel is an exceptionally late breeder, and that he has found it "incubating as late as September 8." He also says that it makes little attempt at nest-building, "though a few sticks are often dragged into the burrow with an evident desire to construct something resembling a nest." He makes no mention in this article of having found the Black Petrel breeding elsewhere than on Coronado Island, but I have an egg which was taken by him on San Benito Island, off the Pacific coast of the Peninsula, on July 26, 1896. In shape it is elliptical ovate, in color dead white, without markings or gloss. It measures 1.38 × 1.04.

At a meeting of the A. O. U. Committee on Nomenclature, held in Washington in 1895, Mr. Ridgway stated that he had sent specimens of his *Oceanodroma townsendi* to Mr. Salvin, who, on comparing them with the type of *O. melania* in the Paris Museum, failed to find any differences by which the two could be distinguished.

Phaëthon aethereus Linn.

Red-billed Tropic Bird.

Phaëthon aethereus Belding, Proc. U. S. Nat. Mus., V. 1883, 545 (Cape Region; Espiritu Santo Islands). Anthony, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 86 (lat. of Cape St. Lucas). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 253 (Espiritu Santo Island).

Mr. Anthony asserts that the Red-billed Tropic Bird "has been regularly met with" in the latitude of Cape St. Lucas and occasionally further north. A specimen was obtained by Mr. Belding at Espiritu Santo Island on February 1, 1882, and a single bird which probably belonged to this species was seen by Mr. Frazar near Montserrat Island on March 4, 1887. In view of all this and of the fact that *P. aethereus* is known to breed in some numbers on San Pedro Martir Island, "a rock about one and a half miles long, nearly as broad, and 1045 feet in height,"[1] situated in the Gulf of California, a little north of latitude 28° and about midway between Lower California and the mainland of Mexico, we may assume that the bird occurs regularly and not infrequently in the waters immediately about the Cape Region proper, although this does not seem to have been as yet definitely established. Of the San Pedro Martir colony Colonel Goss has given us the following interesting account: —

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[1] Auk, IV. 1887, 87.
[2] Pub. II. Pasadena Acad. Sci., 1898, 9.
[3] Auk, XV. 1898, 140–144.

> "The birds breed in holes and crevices on the sides of the steep cliffs that often overhang the water; many were inaccessible. I was therefore able to reach and examine but few of their nesting places. These were without material of any kind for a nest; the egg (for they lay but one) was upon the bare rock. In nearly all, however, I found a young bird, about half grown; from this I think the birds begin to lay as early as the middle of February. With the aid of the Indians, who are expert climbers, I was only able to procure and save seven of their eggs. The ground color is dull grayish white, rather finely and evenly sprinkled with deep claret brown, generally thickest at large end, the specks running largely together, giving the eggs a clouded or marbled look. In form they are ovate. Measurements of the same, 2.31 × 1.71, 2.40 × 1.72, 2.40 × 1.78, 2.26 × 1.71, 249 × 1.81, 2.40 × 1.69, 2.38 × 1.68. When approached the birds within their homes do not attempt to leave, but vigorously defend the same, striking and biting with their strong, pointed, sharp-edged, jagged bills, lacerating the ungloved hand that dares intrude, uttering at the same time a loud, harsh, rapid *che-che-che-che-che-che-che*, — notes of defiance, and often heard in their rival flights. The birds are very beautiful, and cannot fail to attract attention, especially when in the air, by the peculiar rapid stroke of their wings and graceful waving motion of their long whip-like tails."[2]

The Red-billed Tropic Bird has been seen by Mr. Bryant as far north on the Pacific coast of the Peninsula as Cape Colnett (about latitude 31° 15′), and a skull is said to have been found near San Francisco many years ago.[3]

Sula brewsteri Goss.

Brewster's Booby.

Sula leucogastra (not *Pelecanus leucogaster* Boddaert) Belding, Proc. U. S. Nat. Mus., VI. 1883, 352 (near Pichalinque Bay).

Sula sula (not *Pelecanus sula* Linnaeus) Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 253 (near Pichalinque Bay).

An immature Gannet taken near Pichalinque Bay in January, 1883, by Dr. H. Ten Kate, was recorded by Mr. Belding as an example of *Sula leucogastra*, and afterwards referred by Mr. Bryant to *S. sula*. I am informed by Mr. Ridgway, however, that the bird is really *S. brewsteri*, and that there is no valid record of the occurrence of either *S. leucogastra* or *S. sula* in Lower California.

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[1] Goss, Auk, V. 1888, 240.

[2] Goss, *Loc. cit.*, 244.

[3] Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 86, footnote.

Mr. Frazar met with *S. brewsteri* only once — at San José del Cabo, on September 10 — when several were seen flying past over the sea, and one, which came in over the sand-hills, was shot. This bird, although in worn plumage, is immature, the entire head and throat being grayish brown, and the underparts posterior to the breast mixed white and grayish brown.

Colonel Goss, by whom the species was first distinguished and named, found about seven hundred individuals breeding on San Pedro Martir Isle during the latter half of March, 1888, and gives the following description[1] of their nesting habits and eggs: —

> "The birds were not wild, but their nesting places as a whole were not in as exposed situations as those of the Blue-footed; they seemed to prefer the shelves and niches on the sides of the rocks. They lay two eggs, and in all cases collect a few sticks, seaweed, and often old wing or tail-feathers; these are generally placed in a circle to fit the body, with a view, I think, to keep the eggs that lie upon the rock from rolling out. There is but little material on or about the isle out of which a nest can be made.
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> "The birds must commence laying as early as the 10th of February, for I found in many cases young birds from half to two thirds grown — white, downy little fellows with deep bluish black skins — that, in places where they can, wander about regardless of the nests where they were hatched. Average measurement of 17 sets of their eggs, 2.44 × 1.60. In color and form, as well as in size, they are similar to the eggs of the Blue-footed, in fact so near alike that when placed together they cannot be separated with any feeling of certainty; therefore in collecting I was careful to mark each set before they left my hands."

In 1889 Mr. Townsend obtained two specimens on the Georges Islands, where he found the species breeding in abundance.[2] It also nests on Benedicto and Socorro Islands.[3]

There can be little doubt that the Blue-footed Gannet (*S. nebouxii*), which breeds numerously on the islands of San Pedro Martir and Tiburon on the eastern side of the Gulf of California, visits the waters about the southern extremity of the Peninsula more or less frequently, but there is no present evidence to show that this is actually the case.

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[1] Auk, V. 1888, 243.

[2] Proc. U. S. Nat. Mus., XIII. 1890, 138.

[3] Anthony, Osprey, III. 1898, 4–6.

Phalacrocorax dilophus albociliatus Ridgw.

Farallone Cormorant.

Graculus dilophus (not *Pelecanus* (*Carbo*) *dilophus* Swainson) Baird, Proc. Acad. Nat. Sci. Phila., 1859, 301 (Cape St. Lucas), ? 306 (Cape St. Lucas).

Phalacrocorax dilophus cincinnatus (not *Carbo cincinatus* Brandt) Belding, Proc. U. S. Nat. Mus., V. 1883, 545 (Cape Region).

P. [*halacrocorax*] *cincinnatus* (not *Carbo cincinatus* Brandt) Belding, *Loc. cit.*, 548 (La Paz).

Phalacrocorax dilophus albociliatus Ridgway, Proc. Biol. Soc. Wash., II. 1884, 94, 95 (orig. descr.; coast of California to Cape St. Lucas and W. Mexico). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 253–257 (Cape St. Lucas and elsewhere in Cape Region; feeding and nesting habits).

Mr. Belding characterizes this Cormorant (under the name *P. cincinnatus*) as "very common at La Paz in the winter months; rare in March." Mr. Frazar took a male in adult plumage, but without the nuptial plumes, at Carmen Island, on March 6. On March 15 he found about a dozen pairs breeding on a round, high rock, of an acre or less in extent, near San José Island. The nests, which were built on dead cactuses, contained young birds nearly full grown. Mr. Bryant says: —

"The numbers of these birds which congregate at Magdalena Bay is almost incredible. Many mornings I have been attracted by the noise of thousands fishing some distance off shore and have watched through a glass the dense, dark mass as they passed a given point. Those half a mile or more in the rear came flying forward in platoons and alighted at the head of the broad line, making the water turbulent with commotion while their numbers were being constantly augmented by the arrival of stragglers from the sides and rear. Mingled with the myriads of cormorants were often many California brown pelicans plunging for fish, while above all hovered Heermann's gulls, robbing at every opportunity. To all appearances, they were following a great school of fish, astounding numbers of which must be daily consumed by these voracious feeders. . . .

"Cormorants were seen along the *estero* to San Jorge, and in April, 1889, on the lagoons in lower Purisima cañon, but no nesting colonies were found except on Santa Margarita Island. On that island they built upon mangrove bushes bordering a small lagoon. . . .

"Many of the cormorant's nests, in fact all of those first constructed, were upon the same mangroves as were used by the frigate pelicans, but only the highest branches were appropriated by the cormorants. . . .

"When I first visited this colony (January 14, 1888,) a few of the nests contained eggs, and scores of others were in varying stages of construction. The great rush of cormorants to Santa Margarita Island did not occur until April or latter part of March. . . .

"Some of the nests contained fresh eggs as early as January 14, and I was told they had been taken by the people for food two weeks before."

Phalacrocorax penicillatus (Brandt).

Brandt's Cormorant.

Phalacrocorax penicillatus Belding, Proc. U. S. Nat. Mus., V. 1883, 545 (Cape Region), 548 (San José). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 257 (Cape Region).

Mr. Belding states that Brandt's Cormorant was "abundant" at San José del Cabo in April and May, 1882. It also receives nominal mention in his list of species "common to most or all of the localities where collections were made." Mr. Frazar does not refer to it in his field notes, but his collection includes five young birds in the brown plumage taken at La Paz in January.

To the northward of the Cape Region the species has been met with by Mr. Belding at Coronados and Cerros Islands, and at "several intervening points," while Mr. Bryant has found it "at Magdalena Bay and for many miles up the *estero*." Its general range extends from Cape St. Lucas to Washington. It breeds abundantly on the Santa Barbara and Farallon Islands.

Phalacrocorax pelagicus resplendens (Aud.).

Baird's Cormorant.

[*Phalacrocorax pelagicus*] c. *resplendens* Baird, Brewer, and Ridgway, Water Birds N. Amer., II. 1884, 160 (Cape St. Lucas).

P.[*halacrocorax*] *pelagicus resplendens* Ridgway, Man. N. Amer. Birds, 1887, 80 (Cape St. Lucas).

Phalacrocorax pelagicus resplendens A. O. U., Check List, 1895, 44, 45, no. 123 b (Cape St. Lucas).

Phalacrocorax pelagicus Salvin and Godman, Biol. Centr.-Amer. Aves, III. 1901, 152, part (crit.; Cape St. Lucas).

According to Baird, Brewer, and Ridgway's Water Birds, Ridgway's Manual, and the A. O. U. Check List, this form ranges from Washington to Cape St. Lucas and Mazatlan on the western coast of Mexico. I can find no more definite evidence of its occurrence in the waters of the Cape Region, but Mr. Bryant states [1] that it has been "seen near Todos Santos Islands [off the northwestern coast of the Peninsula] upon one occasion in May by Mr. Anthony."

Pelecanus erythrorhynchos Gmel.

American White Pelican.

Pelecanus erythrorhynchus Ridgway, Proc. U. S. Nat. Mus., V. 1883, 534, footnote (San José del Cabo; Cape St. Lucas). Belding, *Ibid.*, VI. 1883, 352 (La Paz).

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[1] Proc. Calif. Acad. Sci., 2d ser., II. 1889, 257.

Pelecanus erythrorhynchos Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 257 (San José del Cabo; Cape St. Lucas; La Paz).

The White Pelican apparently visits the Cape Region only in winter, and then in but small numbers. According to Mr. Ridgway it was found by Mr. Xantus at Cape St. Lucas (date not recorded); and in January and February at San José del Cabo, where Mr. Frazar also saw a flock of about thirty on November 11, 1887. Mr. Belding met with it only once, at La Paz on February 17, 1883, when two were observed. Mr. Frazar says that the people at San José del Cabo are all familiar with the bird, but consider it of rare occurrence. Mr. Bryant's only record is of a flock seen "a little more than one hundred miles northward from Magdalena, on the Pacific Coast." Dr. Cooper mentions the species as "common on the coast of California in winter, though few reach San Diego." It was "occasionally seen in large flocks on Rio Mazatlan, in Western Mexico," by Colonel Grayson, and on the "west coast of Central America" by Mr. Salvin.[1] Hence it sometimes passes well to the southward of Cape St. Lucas.

Pelecanus californicus Ridgw.

California Brown Pelican.

Pelecanus fuscus Belding, Proc. U. S. Nat. Mus., V. 1883, 545 (mortality at Cape St. Lucas and San José; descr.), 548 (San José). Ridgway, *Ibid.*, 545, footnote (crit.).

Pelecanus californicus Anthony, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 83–85 (descr. nest, eggs and habits on San Martin Island). Bryant, *Ibid.*, 257–260 (Cape Region; feeding habits at Magdalena Bay).

Seven specimens of the California Brown Pelican, collected by Mr. Frazar at La Paz on January 28, confirm most satisfactorily the characters proposed by Mr. Ridgway for *P. californicus*, at least as far as the relationship of this form with *P. fuscus* is concerned. The most striking points of distinction between the two species are the larger size of *californicus* and the peculiar coloring of its nape. This with adult birds in perfect nuptial condition is so very dark brown as to look perfectly black in most lights, there being no appreciable tinge of chestnut except on a short space just back of the occiput. The nape of *fuscus* is much lighter and redder, varying in color from chestnut to rich seal brown, which is never sufficiently dark to be mistaken for black. The white-necked winter adults and plain brown young of *californicus* appear to be colored exactly like those of *fuscus*, but the two species may be easily separated by size provided care is taken to compare birds of the same sex, the males of both being considerably larger than the females and the male of *fuscus* sometimes quite as large as the female of *californicus*. The color of the pouch is always lighter in dried skins of *californicus* than in those of *fuscus*, but with freshly killed specimens of the former it is subject to much variation, as the following notes by Mr. Frazar relating to the seven birds just mentioned will show: —

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[1] Baird, Brewer, and Ridgway, Water Birds N. Amer., II. 1884, 136.

COLOR OF POUCH.

Females in full nuptial plumage with black napes.

No. 1. "Anterior half of pouch very dark olive green; posterior half flesh colored."

No. 2. "Anterior half dark olive green shaded with yellow along fold; posterior half light yellowish flesh color tinged with reddish at base."

No. 4. "Anterior two thirds very dark olive green; posterior third flesh color tinged, especially along borders of feathered tracts, with red."

Adult (?) females with white necks.

No. 3. "Anterior two thirds dark olive green; posterior one third red."

No. 5. "Anterior half olive green; posterior half bright red."

Male in full nuptial plumage.

No. 6. "Anterior half dark greenish olive; posterior half chou-chou yellow."

Young in plain brown plumage.

No. 7. "Entire pouch flesh colored. Feet dark. Iris white flecked with gray."

This Pelican is common about La Paz in winter, and both Mr. Belding and Mr. Frazar found it also at San José del Cabo, the former on May 17, 1882, the latter in October, 1887. According to Mr. Frazar's notes it "breeds in March," just where he does not state, but Mr. Bryant[1] "was told that they lay on the southern end of Santa Margarita Island." Mr. Anthony found a colony of about five hundred breeding on San Martin Island, and "according to Mr. A. M. Ingersoll they nest also on Los Coronados Islands" (Bryant). In the lagoon at San José del Cabo Mr. Frazar found one of these birds in a singular dilemma. "The upper mandible had been shut inside the lower, and the bones of the latter had closed over the former so firmly that the poor bird could not open its bill." It was so feeble from starvation that Mr. Frazar caught it, not without difficulty, and at some risk of breaking the mandibles pulled them apart by main force and set the bird free. "It was laughable to see it snap its bill repeatedly as it flew off, evidently not less surprised than relieved to find that it could open and shut it again."

The California Brown Pelican occurs more or less commonly along the Pacific coast as far northward as Gray's Harbor, Washington.[2] It has also been taken at Burrard Inlet, which Mr. Fannin thinks may be the extreme northern limit of its range.[3]

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[1] Proc. Calif. Acad. Sci., 2d ser., II. 1889, 259.

[2] Hubbard, Zoe, III. 1892, 142.

[3] Check List Birds British Columbia, 1891, 8.

Fregata aquila Linn.

MAN-O'-WAR BIRD. FRIGATE BIRD.

Tachypetes aquila BELDING, Proc. U. S. Nat. Mus., V. 1883, 545 (Cape Region), 548 (San José).

Fregata aquila BRYANT, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 260–265 (Cape Region; descr. nest, eggs, habits, and color of fleshy parts at San Margarita Island).

The Frigate Bird is common in winter at La Paz, and in 1882 it was found by Mr. Belding at San José del Cabo as late as May 17. Mr. Frazar notes its "arrival" in autumn on September 9, at the latter locality, and on the 15th of March preceding records finding about fifty birds on a small island to the north of La Paz, "roosting on some cactuses," where they perhaps nested, also, later in the season. Mr. Bryant saw Frigate Birds along the *estero* north of Magdalena Bay, and "at the lagoon in lower Purisima cañon," but most numerously on Santa Margarita Island, where there was a large breeding colony, of which he gives the following interesting description: —

"Going over to Santa Margarita Island from Magdalena Island on January 14, 1888, I saw many of these birds on the wing, some of them idly floating at an immense height, so high as to be almost invisible, higher than I have ever seen hawks (*Buteo*) sailing. Anchoring near shore, we waited until morning before landing. From the boat, the mangroves spoken of under the subject of cormorants, could be seen fairly covered with birds and a long whirling column of others on the wing extended far skyward. Birds were continually coming and going from this place, but none passed within gun-shot of the boat, and during my excursions by boat, more than five hundred miles in all, no man-o'-war bird came near enough for a shot. . . .

"The birds were more quiet after dark, but some sounds could be heard throughout the entire night. At the first faint appearance of dawn, a continuous exodus would commence from the rookery, some of the birds flying high over the island more than four miles to the sea. The mangroves bordering upon the western side only of the lagoon were used for nesting sites, a partial vacancy midway seemed to separate two colonies. The mangroves being higher at the edge of the water, the nests were placed at heights varying from five to twelve feet. Procuring a small boat and the services of a Mexican, I skirted the edge of the lagoon for specimens of eggs and photographs of the rookery, showing the birds in all attitudes. They were usually quite tame but seemed more afraid of me when in the boat than when climbing over and through the mangroves, probably because in the first instance I was more exposed to view. Several birds were caught by hand and some others struck down with an oar as they pitched from the nest to fly past. Upon the water they beat their wings helplessly and were with great difficulty able to rise. In a few cases a bird would miss getting on the wing by coming in contact with another and fall helplessly amongst the branches from which they were scarcely able to extricate themselves. They seemed bewildered by my presence, and did not attempt any resistance. Those which were taken alive were not given an opportunity to use their beaks if they had been so disposed. . . .

"Eggs were collected for food by the Mexicans during the latter part of December, and owing to repeatedly taking them, some were found February 13, 1888, which were in different degrees of incubation, others were quite fresh. The Mexicans had fresh eggs April 27 which they had recently taken.

"The first young were seen in the middle of February; they had been hatched sometime earlier, for although some were nearly naked, others had a full covering of snowy down and the dark scapular pin feathers."

Mr. Grinnell states[1] that the Man-o'-War Bird is "of not infrequent occurrence" along the coast of Los Angeles county, California, in winter, and Mr. T. S. Palmer has recorded[2] the capture of a female at Humboldt Bay on October 5, 1888.

Merganser serrator (Linn.).

Red-breasted Merganser.

Mergus serrator Belding, Proc. U. S. Nat. Mus., VI. 1883, 352 (La Paz).

The Red-breasted Merganser is "common at La Paz in winter" according to Mr. Belding, who seems to have been the first and, indeed, thus far the only observer who has met with it in the Cape Region. Mr. Bryant apparently overlooked the record just quoted, but says[3] that he himself found the birds "tolerably common during March," and also saw some in April in the long *estero* north of Magdalena Bay, adding that "Mr. Belding tells me that he saw a number in San Quintin Bay in May, 1881, and shot one specimen." Further northward, in California, this Merganser is a regular and very common winter bird. There is, I believe, no record of its occurrence south of Lower California.

Lophodytes cucullatus (Linn.).

Hooded Merganser.

Lophodytes cucullatus Ridgway, Proc. U. S. Nat. Mus., V. 1883, 534, footnote (San José del Cabo). Belding, *Ibid.*, VI. 1883, 352 (s. of lat. 24° 30′). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 265 (San José del Cabo; La Paz).

The Hooded Merganser is said by Mr. Ridgway to have been taken at San José del Cabo by Mr. Xantus, in February, and it is given as "rare" south of latitude 24° 30′ by Mr. Belding. Mr. Frazar did not meet with it, and Mr. Bryant gives no record for the central or upper portions of the Peninsula, although "Dr. Cooper found it common . . . along the whole Pacific coast" to the northward of Lower California.[1] The southern limits of its range in winter appear to coincide rather closely with those of the Red-breasted Merganser.

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[1] Pub. II. Pasadena Acad. Sci., 1898, 10.

[2] Proc. Calif. Acad. Sci., 2d ser., II. 1889, 88.

[3] *Ibid.*, 265.

Anas boschas Linn.

Mallard.

Anas boscas Ridgway, Proc. U. S. Nat. Mus., V. 1883, 534, footnote (San José del Cabo). Belding, *Ibid.*, VI. 1883, 352 (s. of lat. 24° 30′).

Anas boschas Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 265 (San José del Cabo; Cape Region).

The Mallard, also, was obtained in winter at San José del Cabo by Mr. Xantus, and it was "shot at several localities" south of latitude 24° 30′, by Mr. Belding, who, according to Mr. Bryant, has found it breeding in the San Rafael Valley. Mr. Anthony states that "quite a number were nesting in the large meadows on the top of the mountain" San Pedro Martir, in May, 1893.[2] Mr. Bryant does not appear to have personally met with the bird in Lower California, nor was Mr. Frazar more fortunate, from which it seems safe to conclude that it is not a common or at least generally distributed species on the Peninsula. This must be due to conditions other than those of latitude, for on the mainland it occurs numerously throughout Mexico and, indeed, ranges as far southward as Panama.

Chaulelasmus streperus (Linn.).

Gadwall.

Chaulelasmus streperus Ridgway, Proc. U. S. Nat. Mus., V. 1883, 534, footnote (San José del Cabo). Belding, *Ibid.*, VI. 1883, 351 (La Paz and s.).

Anas strepera Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 265 (San José del Cabo).

Mr. Xantus found the Gadwall at San José del Cabo in January and February, and Mr. Belding records it as "very common" in winter and early spring near La Paz and to the southward. Mr. Frazar found it "abundant" at San José del Cabo in the autumn of 1887, and notes its arrival on September 27, its increase in numbers up to October 11, and its somewhat diminished numbers on October 26. He makes no mention of its occurrence in November. No specimens are included in his collection.

Colonel Grayson found[3] the Gadwall "abundant from November until late in the spring in the neighborhood of Mazatlan," on the west coast of Mexicc. It breeds as far south as San Pedro, California, according to Dr. Cooper.

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[1] Baird, Brewer, and Ridgway, Water Birds N. Amer., II. 1884, 122.

[2] Zoe, IV. 1893, 230.

[3] Baird, Brewer, Ridgway, Water Birds N. Amer., I. 1884, 508.

Mareca americana (GMEL.).

BALDPATE. AMERICAN WIDGEON.

Mareca americana BELDING, Proc. U. S. Nat. Mus., V. 1883, 548 (San José).
Anas americana BRYANT, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 265 (San José del Cabo).

The only occasion, apparently, on which Mr. Belding met with the American Widgeon was May 17, 1882, when a flock of about twelve were seen at San José del Cabo. At this place, however, Mr. Frazar found the bird common in the autumn of 1887. It was first seen on October 22; after this its numbers steadily increased until by November 9 it was "more numerous than any other species except the Lesser Scaup Duck." The only spring records which I find among Mr. Frazar's notes are of a flock seen on March 6, near San José Island, and of a pair killed on April 1, at Triunfo. Mr. Bryant records a flock of eight "seen in the creek at Comondu," on March 9, 1888; a few others "found at San Juan, on the Gulf side near Loreto some days later," and still others "met with in 1889, at the water hole, San Raimundo."

The American Widgeon breeds chiefly to the northward of the United States, is one of the most abundant Ducks on the California coast in winter, and at the latter season goes at least as far south as Central America.

Nettion carolinensis (GMEL.).

GREEN-WINGED TEAL.

Nettion carolinensis RIDGWAY, Proc. U. S. Nat. Mus., V. 1883, 534, footnote (San José del Cabo). BELDING, *Ibid.*, VI. 1883, 352 (s. of lat. 24° 30′).
Anas carolinensis BRYANT, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 265 (Cape Region).

The Green-winged Teal was observed at San José del Cabo in January and February by Mr. Xantus, and in September and the first half of October by Mr. Frazar, whose first specimen was taken on September 18. Mr. Belding found it moderately common south of latitude 24° 30′. Mr. Bryant apparently did not meet with it at all. It is known to be common in winter in California, and northward as far as Puget Sound, while southward it extends its migrations to Mexico and Central America. A few nest in the western United States, usually at high elevations, but by far the greater number spend the summer to the northward of our northern boundaries.

Querquedula discors (Linn.).

Blue-winged Teal.

Querquedula discors Belding, Proc. U. S. Nat. Mus., V. 1883, 548 (San José).
Anas discors Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 265 (San José del Cabo).

This Teal was not represented in the Xantus collection, and Mr. Frazar did not either obtain or definitely identify it, but Mr. Belding found it common and mated at San José del Cabo on May 17, 1882. According to Mr. Bryant a few were seen at San Ramon, in April, by Mr. Anthony.

The Blue-winged Teal has been taken only a few times in California, and still further northward it appears to be everywhere of uncommon if not rare occurrence on or near the Pacific coast, although it is said to breed sparingly in Alaska. It "was met with in Western Mexico near Mazatlan, by Colonel Grayson, in which region he speaks of it as being a very common species, a few remaining throughout the summer, and probably breeding there."[1]

Querquedula cyanoptera (Vieill.).

Cinnamon Teal.

Querquedula cyanoptera Belding, Proc. U. S. Nat. Mus., V. 1883, 548 (San José).
Anas cyanoptera Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 266 (San José del Cabo).

Mr. Belding mentions the Red-breasted Teal as "rare" in his list of birds seen on May 17, at San José del Cabo, but all of the seven blue-winged birds taken at this place in autumn by Mr. Frazar prove to be *cyanoptera*. They were shot at various dates from August 29 to September 31. Teal supposed to be the same as those preserved were seen at San José del Cabo as late as November 9, but as immature autumnal specimens of *cyanoptera* are so very like those of *discors* that the two can be separated only by the most careful comparison of specimens in hand, it is by no means certain to which species the note last mentioned relates. Mr. Bryant saw a few Red-breasted Teal in Purisima Cañon, and states that many nest at San Rafael Valley, in the extreme northern part of the Peninsula. Mr. Anthony found several pairs breeding in the La Grulla meadows on San Pedro Martir, May, 1893.[2]

This Teal ranges along or near the Pacific coasts of North and South America, "from Puget Sound to Chili, and even, at certain seasons, to the Falkland Islands."[3] Its distribution in summer is not accurately known, but it is supposed to breed throughout much of the vast extent of territory just indicated.

[1] Baird, Brewer, and Ridgway, Water Birds N. Amer., I. 1884, 532.

[2] Zoe, IV. 1893, 230.

[3] Baird, Brewer, and Ridgway, Water Birds N. Amer., I. 1884, 536.

Spatula clypeata (Linn.).

Shoveller.

Spatula clypeata Belding, Proc. U. S. Nat. Mus., V. 1883, 548 (San José). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 266 (San José del Cabo).

At San José del Cabo Mr. Frazar noted the arrival of the Shoveller on October 18, when one was killed from a flock of four. By October 24, it had become common. At the same place Mr. Belding found it in the spring of 1882 as late as May 17. Neither of the observers just mentioned speaks of its occurrence in winter. Mr. Frazar saw a single pair at La Paz on March 2, and others were observed at Comondu and lower Purisima Cañon in April, 1889, by Mr. Bryant.

The Shoveller is common in winter on the Pacific Coast from the mouth of the Columbia River to Mazatlan, and it has occurred as far south as Guatemala. It breeds rather numerously within the United States, but also migrates to high northern latitudes.

Dafila acuta (Linn.)

Pintail.

Dafila acuta Ridgway, Proc. U. S. Nat. Mus., V. 1883, 534, footnote (San José del Cabo). Belding, *Ibid.*, VI. 1883, 352 (s. of lat. 24° 30′). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 266 (Cape Region).

A single Pintail was shot by Mr. Frazar at San José del Cabo on August 29, and on September 2 a flock of about forty were seen. By September 20, they had become abundant. Mr. Ridgway states that Xantus found them in February, and Mr. Belding gives the species as "common" in his list of birds observed south of latitude 24° 30′ in the winter and early spring of 1882–83. Mr. Frazar's collection contains nine specimens. To the northward of La Paz "a few individuals were noticed April 5, 1889, at lower Purisima cañon," by Mr. Bryant; and about "a dozen, including both sexes, at San Rafael Valley, May 12," by Mr. Belding.

On the Pacific Coast the Pintail is said to winter from San Diego, California, almost to the Isthmus of Panama. It breeds numerously in the northern tier of western United States, and from thence northward.

Aythya americana (Eyt.).

Redhead.

Aethyia americana Belding, Proc. U. S. Nat. Mus., VI. 1883, 352 (La Paz).
Aythya americana Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 266 (La Paz).

As the Redhead is not uncommon in winter along the coast of California, and as it has also occurred, at that season, at Mazatlan, on the west coast of Mexico, it was of course to be expected in Lower California, but the only records for this region seem to be those of an adult male shot at La Paz February 12, 1883; a female seen at San Rafael on May 12, 1883, and a male at Trinidad on May 14, all by Mr. Belding.

The Redhead breeds at many places in the more northern United States, but most numerously in British North America, to the northern limits of the Fur Countries, it is said.

Aythya affinis (Eyt.).

Lesser Scaup Duck.

Fulix affinis Belding, Proc. U. S. Nat. Mus., VI. 1883, 352 (s. of lat. 24° 30′).
Aythya affinis Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 266 (Cape Region).

Mr. Belding records the Lesser Scaup as rare, but Mr. Frazar found it abundant at San José del Cabo, where it arrives early in November and remains through the winter. His collection contains three specimens. Mr. Bryant saw a number of small flocks "on Magdalena Bay and some distance along the *estero* in 1888," and in 1889 "shot specimens at lower Purisima cañon and at a water hole, San Raimundo." A few were also observed "on shallow inland water at Ensenada, December, 1885."

The Lesser Scaup Duck is not uncommon in winter in California, and it migrates as far southward as Mexico and Guatemala. It is believed to nest chiefly to the northward of the northern United States.

Aythya collaris (Donov.).

Ring-necked Duck.

Fulix collaris Belding, Proc. U. S. Nat. Mus., VI. 1883, 352 (s. of lat. 24° 30′).
Aythya collaris Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 266 (Cape Region).

The Ring-necked Duck is given by Mr. Belding as "rare" in winter and early spring south of latitude 24° 30′. I cannot find that any one else has reported it from Lower California. It was obtained at Mázatlan by Colonel Grayson, and is known to migrate as far south at least as Guatemala. It breeds to some extent in the northern United States, but chiefly further to the northward. It occurs regularly in winter on the coast of California, but not in any numbers.

Erismatura jamaicensis (Gmel.).

Ruddy Duck.

Erismatura rubida Ridgway, Proc. U. S. Nat. Mus., V. 1883, 534, footnote (San José del Cabo; Laguna de Santiago; Saint Lazaro Mts.). Belding, *Ibid.*, VI. 1883, 351 (La Paz and s.). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 267 (La Paz).

Two adult females, taken at San José del Cabo in October, are somewhat peculiar in respect to the bill which, with both, is much narrower than in any of my specimens from the eastern or central portions of North America. In all other respects they seem to agree perfectly with eastern birds of the same age and sex.

The Ruddy Duck appears to be resident in the Cape Region. It was found by Mr. Xantus at San José del Cabo in December and February, and at Laguna de Santiago, and in the Saint Lazaro Mountains in January. According to Mr. Belding it was "very common" in the "vicinity of La Paz, and southward" in the winter and early spring of 1882–83.

Mr. Frazar met with it first at San José del Cabo, where two were seen on October 18 and a few during the following week. At the time he naturally supposed these birds to be migrants from further north, as indeed they may have been, but on reaching Santiago early in November he found, in the lagoon already mentioned (in connection with the Short-winged Grebe), a large *breeding colony* of Ruddy Ducks, most of which were young of various sizes still following their mothers. Two specimens in his collection taken, on November 16, from a brood of five, cannot have been more than a few days from the egg when killed. The late date at which these young birds were found is somewhat difficult to explain, for in Mexico and Central America, where the species is said to breed numerously, the eggs are laid in May or June.[1] Mr. Frazar was told, however, that the lagoon at Santiago, which, at the time of his visit, was filled with water several feet in depth, dries up every few years, and this fact may have something to do with the unusual season at which the Ruddy Ducks and Short-winged Grebes were breeding there. The Ruddy Duck has been "found nesting at lat. 31° N. by Mr. Anthony" (Bryant), and Mr. Grinnell states that it breeds sparingly in Los Angeles county, California.[2]

Anser albifrons gambeli (HARTL.).

AMERICAN WHITE-FRONTED GOOSE.

Anser albifrons gambeli BRYANT, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 267 (Los Martires).

The American White-fronted Goose is not mentioned in any of the earlier papers relating to the Cape Region, but Mr. Belding told Mr. Bryant "that a hunter (Mr. Fisher) shot one of a group of four at Los Martires, between La Paz and San José del Cabo" (Bryant).

"Mr. Grayson met with this species on the western coast of Mexico, near Mazatlan, where, from the month of September until February, it occurs in considerable flocks, appearing to migrate up and down the southern Gulf shores."[3] It is also abundant in winter in California. Its breeding grounds lie far to the northward of the United States.

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[1] Baird, Brewer, and Ridgway, Water Birds N. Amer, II. 1884, 106.

[2] Pub. II. Pasadena Acad. Sci., 1898, 12.

[3] Baird, Brewer, and Ridgway, Water Birds N. Amer., I. 1884, 452.

Guara alba (Linn.).

White Ibis.

Eudocimus albus Belding, Proc. U. S. Nat. Mus., V. 1883, 545 (Cape Region).
Guara alba Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 268 (Cape Region).

Mr. Frazar notes the White Ibis as common about La Paz and at San José del Cabo, from whence it had been previously reported by Mr. Belding. It appears to be resident, and probably breeds in or near the Cape Region, although this has not been definitely ascertained.

Mr. Bryant found White Ibises "tolerably common at Magdalena Bay, associated in small flocks and making long flights in line from one feeding ground to another. At Santa Margarita Island and along the *estero* they were usually seen roosting upon the mangroves."

The White Ibis is a common bird in Mexico, Central America, and the northern portions of South America. I can find no records for the Pacific coast north of Lower California.

Plegadis guarauna (Linn.).

White-faced Glossy Ibis.

Plegadis guarauna Belding, Proc. U. S. Nat. Mus., V. 1883, 545 (Cape Region), 548 (San José). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 268 (San José del Cabo); Zoe, II. 1891, 189, 190 (San José del Cabo).

At San José del Cabo Mr. Frazar found the White-faced Ibis regularly, in small numbers, during September, but none were met with there after October 1. At Santiago, however, a single bird was observed daily about the lagoon up to November 19. Mr. Belding saw a flock in "April and May" at San José del Cabo.

Mr. Bryant gives no records of the occurrence of this Ibis in the central and northern portions of Lower California, but Mr. Anthony states that "at San Telmo they were usually seen during summer in small numbers about a large marsh above the settlement, and I think they doubtless bred there. Adults and young were shot at San Quintin in October."[1] There is no reason why they should not breed near Cape St. Lucas, about such lagoons as that at Santiago, for instance, but there is no present proof that such is the case.

The range of the White-faced Ibis on the Pacific coast extends from Oregon to Chili and Patagonia.

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[1] Zoe, IV. 1893, 231.

Tantalus loculator Linn.

Wood Ibis.

Tantalus loculator Belding, Proc. U. S. Nat. Mus., V. 1883, 545 (Cape Region), 548 (San José). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 268 (San José del Cabo; La Paz).

The Wood Ibis was found near La Paz by both Mr. Belding and Mr. Frazar. The latter met with it frequently in September and October at San José del Cabo, where Mr. Belding also notes "a pair seen in April and May."

As Mr. Bryant gives no original records, it is to be inferred that he failed to detect the Wood Ibis in the central and upper portions of the Peninsula, but Mr. Anthony states that in autumn a few "are to be found in all of the marshes and streams from Ensenada to Santa Maria."[1] It ranges even further to the northward, for it is not uncommon in Ventura county, California.[2] Whether any nest in Lower California is a matter of grave doubt, — not that the climatic conditions are unfavorable, but because of the apparent lack of suitable breeding grounds. To the southward the Wood Ibis is found in Mexico, Central America, and many parts of South America.

Botaurus lentiginosus (Montag.).

American Bittern.

Botaurus lentiginosus Ridgway, Proc. U. S. Nat. Mus., V. 1883, 533, footnote (Cape St. Lucas; San José del Cabo). Belding, *Ibid.*, VI. 1883, 351 (s. of lat. 24° 30′). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 268 (Cape St. Lucas; San José del Cabo; s. of lat. 24° 30′).

The Xantus collection contains specimens of the Bittern taken at Cape St. Lucas on November 4, and at San José del Cabo on November 29 and 30. At the latter place Mr. Frazar found it common during September and the first week of October, after which it was seen only occasionally, the last individual being observed on November 11. Mr. Belding mentions it as "moderately common" south of latitude 24° 30′ in the winter and early spring of 1882–83.

The Bittern was not observed by Mr. Bryant in the central or northern parts of the Peninsula, but Mr. Anthony says that it is "common in the marshes at Colnett and San Ramon, where it doubtless nests."[3] There is no apparent reason why a few pairs may not breed at such places as Santiago and San José del Cabo, but the present indications are that the bird is merely a winter visitor to the Cape Region. It has occurred as far south as Guatemala.

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[1] Zoe, IV. 1893, 231.

[2] Cooper, Auk, IV. 1887, 90.

[3] Zoe, IV. 1893, 231.

Ardetta exilis (Gmel.).

LEAST BITTERN.

It is somewhat singular that the Least Bittern has not been previously reported from Lower California, for Mr. Frazar found it in considerable numbers at San José del Cabo in September and October. The first individual was seen on August 29, and the last about October 21. The period of greatest abundance was between September 18 and October 11, but the birds varied greatly in numbers from day to day, indicating that they came and departed in successive migratory flights or " waves." None were noted elsewhere.

The range of the Least Bittern is very extensive, including the whole of temperate North America as well as Mexico, Central America, and the northern portions of South America to Brazil. There is some evidence, — not perfectly conclusive, however, — that it breeds as far south as the Lake of Dueñas, Guatemala. It is very common in summer in the interior of California. The Cape Region, therefore, is probably included within its general breeding range, and it would not be surprising to find it nesting about the lagoon at Santiago, which seems to be admirably adapted to its requirements.

Ardea herodias Linn.

GREAT BLUE HERON.

Ardea herodias Baird, Brewer, and Ridgway, Water Birds N. Amer., I. 1884, 15, 16 (discusses the " very light colors " of a Cape St. Lucas specimen, No. 33,134, Nat. Mus). Belding, Proc. U. S. Nat. Mus., V. 1883, 548 (San José). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 268 (San José del Cabo).

The only Great Blue Heron which I have seen from Lower California is an adult male (No. 33,134) in the National Museum, which was taken by Mr. Xantus at San José del Cabo in February, 1860. This specimen has the bill and wing as long as in small specimens of *wardi*, but the tarsus is not longer than in typical *herodias*. The coloring is peculiar in several respects, the upper wing coverts being creamy drab, instead of bluish slate as in *herodias* and *wardi*, the dorsal plumes unusually light colored, and the fore neck, as well as the nape for an inch or more below the occiput, pure creamy white. There is also much less black than usual on the underparts, especially on the breast, which is chiefly creamy white. Mr. Ridgway has already called attention [1] to some of these differences. Should they prove characteristic of the birds of Lower California they would entitle the form to recognition as a distinct subspecies.

Mr. Belding notes this Heron as rare, but Mr. Frazar saw " numbers " about

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[1] Ridgway, *Loc. cit.*

La Paz in January and February, and "a few" at San José del Cabo in the latter part of August. Mr. Bryant found it on Santa Margarita Island and Magdalena Bay, and states that it was rare there. Mr. Anthony has reported it as "common at San Quintin and north of that point, also seen to some extent inland. A colony was found nesting on San Martin Island on April 12."[1]

There are no geographical reasons why the Great Blue Heron should not breed in the Cape Region, and as it often builds its nests on low bushes or even jutting rocks, when tall trees are wanting, it is possible that at least a few birds rear their young near La Paz and San José del Cabo.

Ardea egretta Gmel.

American Egret.

Herodias egretta **Belding**, Proc. U. S. Nat. Mus., V. 1883, 514 (Cape Region), 548 (San José).

Ardea egretta **Bryant**, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 268, 269 (Cape Region; color of fleshy parts).

Mr. Belding includes this Heron in his list of birds observed in the Cape Region between Dec. 15, 1881, and May 17, 1882. On the latter date he noted it at San José del Cabo, where Mr. Frazar also found it in August. It is apparently not numerously represented near the southern extremity of the Peninsula, but is probably resident there.

About Magdalena Bay Mr. Bryant found it "tolerably common" feeding "in small groups or singly along the beach. . . . In April, 1888, they became more common in places along the *estero* and were seen collected on the mangroves above the water. One night while navigating the *estero*, I saw a large flock which may have been a nesting colony, but it was too dark to investigate and by daylight they were far behind."

The range of the American Egret on or near the Pacific coast extends from Oregon to Patagonia, and the bird is said to breed throughout most of the regions embraced within these limits.

Ardea candidissima Gmel.

Snowy Heron.

Garzetta thula **Baird**, Proc. Acad. Nat. Sci. Phila., 1859, 301 (Cape St. Lucas), (?) 305, 306 (crit.; Cape St. Lucas).

Garzetta candidissima **Belding**, Proc. U. S. Nat. Mus., V. 1883, 548 (San José).

Ardea candidissima **Bryant**, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 269 (San José del Cabo).

Small numbers of Snowy Herons were found by Mr. Frazar in winter at La Paz, and in early autumn at San José del Cabo. Several were also seen at the latter place by Mr. Belding on May 17, 1882. To the north of La Paz Mr. Bryant considers the bird rare. He saw it "on a few occasions along the *estero*" north of Magdalena Bay, and at San Juan and Comondu. Mr. Anthony, however, found it "very common all along the coast from El Rosario north." He thinks that it nests at San Ramon, for it was seen there all summer.[1] It probably breeds in or near the Cape Region, also, but this remains to be definitely ascertained. Up to within a few years it was common along the coast of southern California, and it is said to breed at least as far north as Oregon. Southward it is distributed throughout Mexico, Central America, and many parts of South America to Chili and Buenos Ayres.

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[1] Zoe, IV. 1893, 231.

Ardea rufescens GMEL.

REDDISH EGRET.

Dichromanassa rufa BELDING, Proc. U. S. Nat. Mus., V. 1883, 544 (Cape Region), 548 (San José).
Ardea rufescens BRYANT, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 269 (Cape Region).

Mr. Belding found this Heron common in the Cape Region in the winter and spring of 1881–82, but he states that it was rare at San José del Cabo on May 17, 1882. He emphasizes the fact that none were seen in white plumage. Mr. Frazar met with it at both La Paz and San José del Cabo, but not commonly at either place. His single specimen (No. 18,146, ♀, La Paz, January 11) is a "red" bird.

Mr. Bryant gives the Reddish Egret as "tolerably common at Santa Margarita Island, which was probably a night roosting place for many amongst the mangroves. Ten were seen in one flock on February 14, 1888." Mr. Anthony states that the species is "not uncommon at San Quintin."[2]

The locality last mentioned is apparently the most northern one on the Pacific coast from which the bird has been reported. To the southward it is found in Mexico, Guatemala, and northern South America.

Ardea tricolor ruficollis (GOSSE).

LOUISIANA HERON.

Hydranassa tricolor ludoviciana BELDING, Proc. U. S. Nat. Mus., V. 1883, 544 (Cape Region), 548 (San José).
Ardea tricolor ruficollis BRYANT, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 269 (Cape Region).

Mr. Belding records the Louisiana Heron as less common at La Paz than the Reddish Egret, and "rare" at San José del Cabo on May 17, 1882. Mr.

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[1] Zoe., IV. 1893, 231.

[2] *Ibid.*, 231

Frazar, however, found it common at both these places in 1887. Mr. Bryant "saw two flying above the mangrove tops of the *estero*" north of Magdalena Bay in March, 1888, and during the same month of the following year noted a small flock rising "from the lagoon on Santa Margarita Island." This Heron, as well as the Reddish Egret, probably breeds on or near the southern coasts of the Peninsula, but is not positively known to do so. It has not as yet been detected in California, but it occurs on the western coast of Mexico and southward to Guatemala.

Ardea virescens frazari Brewst.

FRAZAR'S GREEN HERON.

[*Ardea*] *virescens* Coues, Key N. Amer. Birds, 1872, 268, 269, part.

Ardea virescens Coues, Check List, 1873, 89, no. 457, part. A. O. U., Check List, 1886, 137, no. 201, part.

Butorides virescens Ridgway, Nom. N. Amer. Birds (Bull. U. S. Nat. Mus., no. 21), 1881, 42, no. 494, part. Coues, Check List, 2d ed., 1882, 107, no. 663, part. Sharpe, Cat. Birds Brit. Mus., XXVI. 1898, 186–191, 280, part (crit.; synonymy; Lower California).

(?) *Butorides virescens* (not *Ardea virescens* Linnaeus) Belding, Proc. U. S. Nat. Mus., V. 1883, 544 (Cape Region).

Ardea virescens frazari Brewster, Auk, V. 1888, 83 (orig. descr.; type from La Paz). A. O. U. Comm., Suppl. to Check List, 1889, 6; Check List, abridged ed., 1889, and 2d ed., 1895, no. 201 a. Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 269 (Cape Region; Santa Margarita Island; Comondu). Ridgway, Man. N. Amer. Birds, 2d ed., 1896, 586 (descr.; vicinity of La Paz).

Butorides virescens frazari Coues, Key N. Amer. Birds, 4th ed., 1894, 905 (descr.; vicinity of La Paz).

[*Butorides*] *frazari* Sharpe, Hand-list, I. 1899, 200.

This race of the Green Heron, distinguished from *A. virescens* by its larger size and deeper, richer coloring, was discovered in 1887 by Mr. Frazar, who found it only at La Paz. His notes state that it frequented mangrove thickets about the shores of the Bay, where it was "common" during February and March, but as he mistook it for our eastern bird he preserved only two specimens. It is probably the resident and characteristic form of this locality, as well as of some of the neighboring islands, and it may range considerably further to the northward along one or both coasts of the Peninsula, for Mr. Bryant has reported seeing it in small numbers "at Santa Margarita Island and along the *estero*, also at Comondu. No specimens were secured," but Mr. Bryant thinks that "a skin in the collection of the California Academy of Sciences from Magdalena Bay, is probably referable to this form." All these records require confirmation, however, for at the time they were made Mr. Frazar's bird was the only Green Heron known to occur in Lower California.

Ardea virescens anthonyi Mearns.

Anthony's Green Heron.

(?) *Butorides virescens* (not *Ardea virescens* Linnaeus) Belding, Proc. U. S. Nat. Mus., V. 1883, 544 (Cape Region).

The Green Herons taken by Mr. Frazar at San José del Cabo seem to be all *A. v. anthonyi.* At least they are much too large for *virescens*, while the young (nine in number) agree perfectly with young specimens of *anthonyi* from California. Like the latter they have the white on the tips of the primaries and secondaries, and the light edging on the wing coverts much broader and more conspicuous than in the young of our eastern bird. The three adults are very unlike the only two known specimens of *frazari* (both of which are fully mature), having the chestnut of the head and neck even lighter and more rufous than in *virescens*, instead of deeper and more glaucous, as is the case with *frazari*. In this respect, as well as in size, they are typical of *anthonyi*, but in respect to the extent and distribution of the whitish or rusty markings on the wings and under parts they agree better with *virescens*.

Anthony's Green Heron is probably only a transient visitor to the Cape Region. At least Mr. Frazar did not meet with it in winter or early spring at La Paz nor anywhere during the breeding season. It was common at San José del Cabo, however, from August 25 to about October 15 ; after the latter date only an occasional straggler was noted, the latest on November 11. Rather curiously, all the birds seen at the locality just named occurred along the sand bars and sandy shores of the river, although there were plenty of muddy creeks and pools in the immediate neighborhood.

The general range of this form of the Green Heron is not, as yet, definitely known. It has been found breeding in Arizona and southern California, and I have a typical example (taken on May 13) from Franktown, Nevada. It is said to be represented in the Smithsonian Collection by specimens from the Valley of Mexico and from Santa Efigenia, Tehuantepec.

Nycticorax nycticorax naevius (Bodd.).

Black-crowned Night Heron.

Nycticorax griseus naevius Belding, Proc. U. S. Nat. Mus., V. 1883, 544 (Cape Region).

Nycticorax nycticorax naevius Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 270 (Cape Region).

This Night Heron was found in the Cape Region by both Mr. Belding and Mr. Frazar. The latter observer noted it at La Paz in winter, and at San José del Cabo in October. "A few were seen at Santa Margarita Island in the month of February, 1888," by Mr. Bryant.

If the Black-crowned Night Heron does not nest in Lower California, it must be because the local conditions are in some way unfavorable, for its general breeding range includes the whole of temperate North America and most of South America, also.

Nycticorax violaceus (LINN.).

YELLOW-CROWNED NIGHT HERON.

Nyctherodius violaceus BELDING, Proc. U. S. Nat. Mus., V. 1883, 544 (Cape Region), 548 (San José).

Nycticorax violaceus BRYANT, Proc. Calif. Acad. Sci., 2d ser., II 1889, 270 (Cape Region).

Mr. Belding found the Yellow-crowned Night Heron "very common" on May 17, 1882, at San José del Cabo, where, according to Mr. Frazar, it also occurs numerously in autumn, "arriving early in September." The latter observer also met with it in considerable numbers at La Paz in winter. About Magdalena Bay "many night herons were nesting in April, 1888, in a mangrove thicket bordering the long *estero;* they all appeared to be of this species. When alarmed by the passing of the sail-boat, they left the bushes and collected along the water's edge, where I counted eighty" (Bryant).

On the Pacific coast the Yellow-crowned Night Heron is not known to go as far northward as California. It ranges southward to Central America and northern South America.

Rallus beldingi RIDGW.

BELDING'S RAIL.

Rallus beldingi RIDGWAY, Proc. U. S. Nat. Mus., V. 1882, 345, 346 (orig. descr.; type from Espiritu Santo Islands); VI. 1883, 158, footnote (crit.; S. Lower Calif.). BELDING, *Ibid.*, V. 1883, 545 (Espiritu Santo Islands). BAIRD, BREWER, and RIDGWAY, Water Birds N. Amer., I. 1884, 356, 357 (descr.; crit.; Espiritu Santo Island; La Paz). A. O. U., Check List, 1886, 140, no. 209. BRYANT, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 270 (Espiritu Santo Island; La Paz). SHARPE, Cat. Birds Brit. Mus., XXIII. 1894, 10 (descr.; La Paz; Espiritu Santo Island, etc.; subsp. of *Rallus elegans*). COUES, Key N. Amer. Birds, 4th ed., 1894, 888 (descr.; Espiritu Santo Island).

[*Rallus*] *beldingi* SHARPE, Cat. Birds Brit. Mus., XXIII. 1894, 7 (key to species); Hand-list, I. 1899, 93.

R.[*allus*] *beldingi* RIDGWAY, Man. N. Amer. Birds, 2d ed., 1896, 138 (descr.; La Paz; Espiritu Santo Island, etc.).

The type specimen of this Rail was taken by Mr. Belding on Espiritu Santo Island, but Mr. Frazar found the bird only about the shores of the Bay near La Paz, where it inhabits mangrove thickets bordering mud flats or intersected by small tidal creeks. It is evidently rare here, for Mr. Frazar shot only two specimens, and saw or heard less than half a dozen in all.

"Rails were heard in mangrove swamp on Santa Margarita Island, Magdalena Island, and for one hundred and twenty miles up the *estero*. They were clapper rails, but whether *R. beldingi* I cannot say" (Bryant).

On the basis of this scanty evidence it is impossible to do more than speculate concerning the habits and distribution of Belding's Rail. The bird is apparently confined to the southern half of the Peninsula, for on the northwest coast (San Quintin Bay) its place is taken by the California species, *Rallus obsoletus*. *R. beldingi* is probably resident wherever found, but as yet even this cannot be positively asserted.

Rallus virginianus Linn.

Virginia Rail.

Mr. Frazar found the Virginia Rail only at San José del Cabo, where he killed a specimen on October 24 and another on November 4. He is very sure that he saw three others, the first on October 3, the second on October 6, and the third on November 4. The bird has not been previously reported from the Cape Region, but "Mr. Anthony has taken it at San Quintin in winter." [1]

It is abundant in the winter months in different parts of Mexico, and it has been obtained as far south as Guatemala. In California it is said to occur at all seasons of the year, and it may be resident, locally, in Lower California, also.

Porzana carolina (Linn.).

Sora. Carolina Rail.

Porzana carolina Belding, Proc. U. S. Nat. Mus., V. 1883, 547 (San José del Cabo); VI. 1883, 351 (La Paz and s.). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 270 (San José del Cabo; La Paz).

Mr. Belding, in his list of birds observed in the "vicinity of La Paz and southward" between December 15, 1882, and March 23, 1883, mentions the Sora as "rarely seen," and in a paper relating to his experience of the preceding year he also refers to it incidentally, as one of the birds found between April 1 and May 17 in the marsh at San José del Cabo. These allusions, although vague and unsatisfactory, indicate that at least a few Soras pass the winter in the Cape Region, and that others occur there rather late in the spring. Mr. Frazar's experience unfortunately furnishes nothing bearing directly on these points, for he met with the Sora only in autumn, at San José del Cabo. It was very numerous there during the latter half of September and first ten days of October, after which only a few stragglers were noted, the last on October 18. It was usually seen in beds of tall reeds and cat-o'-nine tails growing about the margins of the lagoon, but on one occasion (September 20), when an exceptionally high tide had broken over the beach and raised the water several feet above its usual level, the birds were driven from their favorite haunts and forced to seek shelter in a neighboring wheat field, where many were flushed and killed.

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[1] Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 270.

The Sora was seen by Mr. Anthony "in spring along the coast north of lat. 31°" (Bryant). It is said to be common in California in winter, and according to Mr. Grinnell is found in Los Angeles county at all seasons, nesting in May among marsh grass or tules in swampy places.[1] Its migrations extend to northern South America.

Gallinula galeata (Licht.).

FLORIDA GALLINULE.

It is singular that up to this time no one has reported the Florida Gallinule from Lower California, for Mr. Frazar found it both at San José del Cabo and Santiago. At the former place the first birds, three in number, were seen on September 13. A few days later they became abundant, remaining so up to October 10, after which their numbers diminished rapidly until, by the end of the month, all had apparently disappeared, the last being seen on the 28th. They frequented both the river and the lagoon at its mouth, but during the high tide already mentioned a good many, in company with Carolina Rails, sought shelter in a wheat field. At Santiago several were observed as late as November 15 in the beds of tule about the lagoon, where it is possible they were intending to winter, and where a few may breed, also, although neither surmise is warranted by any present evidence.

The Florida Gallinule is found from California to Chili on or near the Pacific coast, and it probably breeds (more or less locally) throughout this extended range.

Fulica americana Gmel.

AMERICAN COOT.

Fulica americana Baird, Proc. Acad. Nat. Sci. Phila., 1859, 301, 306 (Cape St. Lucas). Belding, Proc. U. S. Nat. Mus., V. 1883, 545 (Cape Region). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 271 (Cape Region).

Mr. Belding includes the Coot in his list of birds seen in the winter and spring of 1881–82, but mentions no special localities nor dates. Mr. Frazar found it only at San José del Cabo and Santiago. At the former place it arrived on September 10, and was very numerous during October and up to the date of Mr. Frazar's departure, November 13. At Santiago a large number were seen daily, during the latter half of November, in the lagoon already described. "Mr. Anthony found them very abundant all winter in the northern portion of the peninsula, and breeding where fresh water was in sufficient quantity. He found a pair nesting on San Pedro Martir in May, at an altitude of 8,200 feet" (Bryant). Others have been seen by Mr. Bryant at Comondu, San Juan (April), and "lower Purisima cañon, where they were probably breeding."

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[1] Pub. II. Pasadena Acad. Sci., 1898, 15.

The Coot has a very extended range on or near the Pacific coast, occurring numerously nearly everywhere from Alaska to northern South America, and breeding wherever the local conditions are suited to its tastes, without much apparent regard for considerations of latitude or mean temperature.

Crymophilus fulicarius (Linn.).

Red Phalarope.

Phalaropus fulicarius Belding, Proc. U. S. Nat. Mus., V. 1883, 545 (Cape Region).
Crymophilus fulicarius Bryant, Proc. Calif. Acad. Sci, 2d ser., II. 1889, 271 (La Paz Bay).

Although the Red Phalarope has received but nominal mention on the part of Mr. Belding, that observer, according to Mr. Bryant, has killed two specimens in La Paz Bay, the only ones, apparently, which have ever been taken in the Cape Region. Birds supposed to belong to this species have also been seen on several occasions off the Pacific coast of the Peninsula by both Mr. Bryant and Mr. Anthony, but as none of them have been secured their identification is perhaps open to some doubt.

The Red Phalarope breeds only in high northern latitudes. The southern extension of its winter range in the Western hemisphere has not been definitely ascertained, but in the Eastern it has occurred in northern Africa and at Calcutta, India. It visits the coast of California in moderate numbers at its seasons of migration, occurring oftenest, apparently, in autumn.

Phalaropus lobatus (Linn.).

Northern Phalarope.

Two adult Northern Phalaropes, both females, shot by Mr. Frazar on August 29, retain much of the breeding plumage, especially on the front and sides of the neck, which are faded but distinct rufous. A male taken on September 27 is in excessively worn and faded summer plumage, which is interspersed with a few feathers of the winter dress. All the other birds in the series appear to be adults in winter plumage, or young in their first autumn plumage, intermixed, in some specimens, with more or less feathers of the winter plumage.

Mr. Frazar found the Northern Phalarope not uncommon in early autumn at

San José del Cabo, where fourteen specimens were taken, the first on August 29, the last on October 7. They frequented the large fresh-water lagoon just back of the beach, and as many as six or seven were sometimes to be seen at one time scattered about on the surface of the water. A few were also met with in the creeks which connected with this lagoon. Most of the birds examined had lost one or more toes, and two or three an entire foot, and part of the tarsus, also, while others showed gaping wounds on the breast. These mutilations were probably caused by the bites of fishes. This species has not been previously reported from the Cape Region, but "Mr. Belding secured three specimens at San Rafael, May 16" (Bryant).

The Northern Phalarope is not known to breed south of the Arctic regions. It occurs abundantly at its seasons of migration along the coast of California, and in winter ranges as far southward as Guatemala and the Isthmus of Tehuantepec.

Steganopus tricolor Vieill.

WILSON'S PHALAROPE.

Steganopus wilsoni Belding, Proc. U. S. Nat. Mus., VI. 1883, 351 (La Paz and s.).
Phalaropus tricolor Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 271 (San José del Cabo).

But three Wilson's Phalaropes are known to have been taken in Lower California. Mr. Belding obtained the first some time in the spring of 1883, at San José del Cabo, where Mr. Frazar collected the other two in August, 1887. One of Mr. Frazar's specimens, shot on the 30th of the month, is in the gray winter plumage, but appears to be an old bird. The other, killed on the 31st, is a young bird in a plumage intermediate between that of autumn and winter. Both are males.

This species is doubtless rare in Lower California, for unlike the Northern and Red Phalaropes it shuns salt water, and seldom visits either sea-coast of North America, preferring, at all seasons, fresh-water ponds and rivers in the interior, where its breeding range extends from the more northerly United States to about latitude 55° N. In winter it is said to be rather common on some of the interior lakes in Mexico, and it has once been found in Guatemala.

Recurvirostra americana Gmel.

AMERICAN AVOCET.

Recurvirostra americana Belding, Proc. U. S. Nat. Mus., VI. 1883, 351 (s. of lat. 24° 30′). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 271 (La Paz).

Mr. Frazar met with the Avocet only four times in all, at La Paz on February 3, and at San José del Cabo on October 15, 18, and 26. On the first three occasions single birds were seen, on the last a flock of eight. Mr. Belding gives the species as "not common"; Mr. Bryant does not mention finding it at all; Mr. Anthony says that it is "not uncommon at San Quintin, Colnett and Ensenada" in the northern part of the Peninsula, where it occurs in autumn, only "about the fresh water marshes."[1]

In Los Angeles county, California, it is "found in marshy districts in varying numbers throughout the year," and it "breeds commonly in the vicinity of the Alamitos swamps and Nigger Slough."[2] In winter it migrates as far southward as Guatemala.

Himantopus mexicanus (Müll.).

Black-necked Stilt.

Himantopus mexicanus Ridgway, Proc. U. S. Nat. Mus., V. 1883, 534, footnote (Sierra de Santiago; Cape St. Lucas; San José del Cabo). Belding, *Ibid.*, VI. 1883, 352 (s. of lat. 24° 30′). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 271 (La Paz).

Between September 14 and October 19 Mr. Frazar took four specimens of the Stilt at San José del Cabo. He notes it as "not at all common" there, and did not meet with it elsewhere. Xantus found it at Sierra de Santiago in January, and at Cape St. Lucas and San José del Cabo in February. Belding gives it as "not common" in his list of birds found south of latitude 24° 30′. There is no evidence that it breeds in this region.

In the northwestern part of the Peninsula Mr. Anthony has seen the Stilt "during migrations about fresh water" (Bryant). According to Mr. Grinnell it is "common in spring and fall on the margins of ponds and marshes" in Los Angeles county, California, where it also "breeds locally in considerable numbers. Evan Davis has taken eggs at Alkali Lakes near Santa Ana from the first of May until August."[3]

The Stilt apparently goes further southward in winter than the Avocet, invading South America to Peru and Brazil. It breeds at least as far to the southward as Matamoras, Mexico, and as far to the northward as Oregon.

Gallinago delicata (Ord).

Wilson's Snipe.

Gallinago wilsoni Ridgway, Proc. U. S. Nat. Mus., V. 1883, 534, footnote (San José). Belding, *Ibid.*, VI. 1883, 351 (La Paz and s.).

Gallinago delicata Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 271, 272 (San José del Cabo; La Paz).

Mr. Belding notes Wilson's Snipe as "rare," but Mr. Frazar found it in considerable numbers at both San José del Cabo and Santiago. Near the former place three were seen as early as August 28; the date of greatest abundance was October 18, after which there was a rapid decrease, the last bird being seen on November 9. At Santiago, however, these Snipe were numerous on November 17, and a single bird was flushed near the summit of the Sierra de la Laguna, on November 28. Mr. Bryant "saw a few at Comondu in March and April, 1888," and Mr. Anthony found them rare "in the region embraced in his explorations (San Fernando to Ensenada)" (Bryant).

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[1] Zoe, IV. 1893, 231.

[2] Grinnell, Pub. II. Pasadena Acad. Sci., 1898, 16.

[3] *Ibid.*

Wilson's Snipe migrates as far southward as Central America, and breeds from Oregon northward.

Macrorhamphus scolopaceus (Say).

LONG-BILLED DOWITCHER.

At San José del Cabo Mr. Frazar killed nine Long-billed Dowitchers on August 28, and during September and October large flocks were seen almost daily. They were also very common at Santiago in November, the latest date mentioned in Mr. Frazar's notes being the 17th. In view of these facts it seems curious that the bird has not been previously reported from this region. A little farther north, however, Mr. Bryant has found it[1] "common at Magdalena Bay, where small flocks associated with willet and godwit," and still more plentiful on mud flats along the *estero* to the northward of this Bay, where it occurred in March.

Red-breasted Snipe, presumably of this species, were found commonly on the Pacific coast of Guatemala by Mr. Salvin,[2] and specimens are said to have been taken in Chili. Dr. Brewer gives its breeding range as extending "from lat. 44° N. to the Arctic Ocean."[3]

Tringa maculata Vieill.

PECTORAL SANDPIPER.

This Sandpiper, also, is an addition to the fauna of the Cape Region. Indeed, it does not seem to have been previously reported from any part of Lower California. It is represented in Mr. Frazar's collection by nine specimens taken at various dates between September 2 and October 24 at San José del Cabo, where, according to the accompanying notes, it occurred in considerable numbers.

The Pectoral Sandpiper is "not rare at San Francisco Bay in winter," according to Dr. Cooper,[4] but it does not appear to have been found in any other part of California. It is believed to breed only within the Arctic regions, but it migrates southward in winter as far as Chili, and even to northern Patagonia.[1]

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[1] Proc. Calif. Acad. Sci., 2d ser., II. 1889, 272.

[2] Ibis, 1865, 191.

[3] Baird, Brewer, and Ridgway, Water Birds N. Amer., I. 1884, 197.

[4] Auk, III. 1886, 124.

Tringa bairdii (Coues).

Baird's Sandpiper.

Still another Sandpiper new not only to the Cape Region, but to the Peninsula at large, is the present species, of which Mr. Frazar took four specimens at San José del Cabo between September 3 and 13. According to Baird, Brewer, and Ridgway, it had not been "recorded from the Pacific coast of the United States"[2] when the Water Birds appeared.

Baird's Sandpiper "was found breeding on the Barren Grounds, June 24, by Mr. MacFarlane,"[3] and is believed to winter in South America, where it goes as far south as Peru and Chili. Its migrations, in North America at least, are performed chiefly through the interior. Although it is supposed to be normally confined to the New World, a specimen has been taken at Walfish Bay in South Africa.

Tringa minutilla Vieill.

Least Sandpiper.

Actodromas minutilla Ridgway, Proc. U. S. Nat. Mus., V. 1883, 534, footnote (Todos Santos).

Tringa minutilla Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 272 (Todos Santos).

Mr. Ridgway's mention of a specimen without date taken by Xantus at Todos Santos (on the west coast) appears to be the only previous record of the occurrence of this species in the Cape Region. Nevertheless it visits the Gulf coast of the Peninsula in considerable numbers, both in spring and autumn, for Mr. Frazar took two specimens on March 6, at Carmen Island, and no less than eleven the following autumn at San José del Cabo. At the latter place they were first seen on August 23, and by the 28th had become numerous. Through September they were met with almost daily, but none were observed after October 3. Mr. Bryant says that "Mr. Anthony noticed them at San Quintin Bay. At Magdalena Bay they were seen in small flocks and specimens taken; also at lower Purisima cañon."

The Least Sandpiper breeds chiefly if not exclusively north of the United States. It is of common occurrence on the coast of California in winter, when it also visits central and northern South America, as well as the Galapagos Islands.

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[1] Ibis, 1877, 43.

[2] Baird, Brewer, and Ridgway, Water Birds N. Amer., I. 1884, 230.

[3] Baird, Brewer, and Ridgway, *Loc. cit.*, 232.

Tringa alpina pacifica (Coues).

Red-backed Sandpiper.

Pelidna alpina americana Belding, Proc. U. S. Nat. Mus., VI. 1883, 351 (s. of lat. 24° 30′).

Mr. Belding found the Red-backed Sandpiper "very common in winter" south of latitude 24° 30′, in 1882–83. It has not been reported from this region by any one else, and was not met with by Mr. Frazar. Mr. Bryant is not sure that he "saw any of this species at Magdalena Bay." He states that Mr. Belding "mentions it as abundant at San Quintin Bay, May 2, 1882, but rare by May 10."

The American Red-backed Sandpiper is not known to occur south of Lower California on the Pacific coast, and the greater number of individuals probably winter north of San Francisco, for it is a hardy bird and quite able to endure rather severe frost. Its breeding grounds lie exclusively north of the United States.

Ereunetes occidentalis Lawr.

Western Sandpiper.

Ereunetes pusillus occidentalis Belding, Proc. U. S. Nat. Mus., V. 1883, 545 (Cape Region).
Ereunetes occidentalis Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 272 (Cape Region).

Mr. Belding gives this species without remarks in his list of birds noted between December 15, 1881, and May 17, 1882. Mr. Frazar found it only at San José del Cabo, where it was abundant during the last week of August and most of September, the last specimen being taken on the 30th of the latter month. Mr. Bryant mentions seeing "a few in a flock of *T. minutilla*" at Magdalena Bay, and adds that Mr. Belding found it abundant at San Quintin Bay "May 2, 1882, but rare by May 10." Mr. Grinnell states that it visits the coast of Los Angeles county, California, "in immense flocks during September and April."[1]

The Western Sandpiper breeds in Alaska, and winters on the coast of Central America.[2]

[1] Pub. II. Pasadena Acad. Sci., 1898, 17.

[2] Seebohm, Geogr. Distr. Charadriidae, 1888, 404.

Calidris arenaria (Linn.).

Sanderling.

Calidris arenaria Baird, Proc. Acad. Nat. Sci. Phila., 1859, 301, 306 (Cape St. Lucas). Ridgway, Proc. U. S. Nat. Mus., V. 1883, 534, footnote (Cape Region). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 272 (Cape Region).

There is a nominal mention of the Sanderling in Professor Baird's notes on the Xantus collection of 1859, but Mr. Belding does not include it in any of his lists. It was found by Mr. Frazar only at San José del Cabo, where, on the sea beach, three specimens were seen and two shot on October 18, and four seen and three taken on October 22. The species winters abundantly on the northwestern coast of the Peninsula according to Mr. Bryant, who also records a single bird obtained "on Santa Margarita Island March 4, 1889, from a flock of *Ægialitis nivosa*."

The Sanderling is a nearly cosmopolitan species, whose wanderings cover almost the entire globe, but it breeds only in Arctic and Subarctic regions. On the west coast of America its winter range extends to Patagonia. It is "common throughout the winter in flocks on the sandy sea beaches" of Los Angeles county, California, where it regularly lingers until the middle of May, and sometimes as late as the first week of June.[1]

Limosa lapponica baueri (Naum.).

Pacific Godwit.

Limosa lapponica novae-zealandiae Belding, Proc. U. S. Nat. Mus., V. 1883, 545 (Cape Region).

Limosa lapponica baueri Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 273 (La Paz).

A bare mention of the name of this Godwit in Mr. Belding's list of the Birds found in the Cape Region between December 15, 1881, and May 17, 1882, constitutes the only record of its occurrence in North America, south of Alaska, according to Mr. Ridgway,[2] who informs me that the authenticity of the record is open to no doubt, for the head of the specimen is preserved in the National Museum. It is labeled simply "No. 86,418, La Paz," and, without question, is that of an adult *L. l. baueri* in winter plumage. Mr. Belding writes me concerning this bird: — "I can only say I killed it at La Paz, but was not aware that I had taken anything but the common kind until Professor R. informed me to the contrary. I believe I sent only a head and wings. I had hurt my right hand by a large dead cactus that toppled over and fell on me. I could not skin a bird for more than a month. That accounted mostly for the fragments of some water birds I sent to the Smithsonian."

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[1] Grinnell, Pub. II. Pasadena Acad. Sci., 1898, 17.

[2] Baird, Brewer, and Ridgway, Water Birds N. Amer., I. 1884, 258.

The Pacific Godwit breeds abundantly in Alaska, where it was first found by Dall, and afterwards by Elliott, Nelson, and Turner. Mr. Nelson in his Report upon Natural History Collections made in Alaska between the years 1877 and 1881 (pp. 115, 116), gives a good account of its habits, changes of plumage, etc. The members of this Alaska colony are supposed to cross the Pacific Ocean during migration, and to winter, in company with the birds of the same species which breed in the northern portions of eastern Asia, in the islands of the Malay Archipelago, Australia, the New Hebrides, Norfolk Island, and New Zealand.

Totanus melanoleucus frazari, subsp. nov.[1]

GRAY YELLOW-LEGS.

Totanus melanoleucus (not *Scolopax melanoleucus* GMELIN) RIDGWAY, Proc. U. S. Nat. Mus., V. 1883, 534, footnote (San José; Cape St. Lucas). BELDING, *Ibid.*, VI. 1883, 351 (s. of lat. 24° 30′). BRYANT, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 273 (n. of La Paz).

Subspecific characters: — Slightly larger than *T. melanoleucus*; the bill somewhat slenderer, the general coloring much grayer, the white streaks of the nape and top of head broader; the dark streaks of the jugulum, breast and sides of neck and the dark bars on the sides of the body fewer, finer and fainter; the sides of the head whiter, with less dark mottling.

Winter plumage: — Male (No. 17,815, collection of William Brewster, San José del Cabo, Lower California, October 27, 1887; M. Abbott Frazar). Above light ashy gray, the feathers of the back bordered with ashy white; those of the scapulars and wing coverts notched on both webs with brownish white; upper tail coverts white with a few dark bars; primaries dark slaty, lighter, and with more or less grayish mottling on the inner webs of most of the feathers; tail white, all the feathers barred with dusky; the middle feathers grayish with obscure dusky bars; under parts pure white, the jugulum, fore part of breast and sides of neck finely streaked with obscure dusky; sides irregularly marked with grayish and dusky; under wing coverts and axillars white with obscure V shaped markings of dull slaty; under tail coverts pure white, with a few narrow dark bars; sides of head white with fine, sparse specks of dusky everywhere, excepting over a space extending from above the eye to the base of the culmen, where the white is immaculate; a nearly solid patch of dusky on the anterior portion of the lores. Wing, 6.95; tarsus, 2.30; length of bill from nostril, 1.86; depth at nostril, .25.

The bird above described, like all of my twenty or more additional specimens which unmistakably belong to the same race, is in winter plumage.

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[1] Of the several names which have been bestowed on the Greater Yellow-legs all appear to relate to the eastern bird, except *Totanus chilensis* PHILIPPI, Arch. f. Nat., pt. I. 1857, 264 (Chili), which is indeterminable. I have named the new bird for Mr. M. Abbott Frazar.

What the summer dress is like I am not prepared to state, but I have reasons for suspecting that breeding examples of the eastern and western (or interior) forms are not easily distinguishable from one another. I was at first inclined to think that the bird which I have named *frazari* was merely the adult of *melanoleucus* in winter plumage, but a careful examination of Mr. Frazar's specimens has satisfied me that several of them are young, and on comparing them with a good series of both adults and young of *melanoleucus*, shot at corresponding dates in New England, I have become convinced that the differences to which I have just called attention cannot be satisfactorily explained other than by the assumption that they characterize two distinct geographical races. A rather puzzling feature of the case is that I have several specimens perfectly typical of *melanoleucus* from British Columbia, and a dozen or more equally characteristic of *frazari* from Georgia and Florida, but birds of such free powers of flight as Yellow-legs are notorious wanderers, and it may be that *frazari* breeds only in the *interior* of British America and that it does not visit either the Atlantic or Pacific coast until it has passed well to the southward of the northern boundary of the United States.

This hitherto unrecognized form of the Greater Yellow-legs is, no doubt, the bird which Mr. Xantus found at San José del Cabo (December) and Cape St. Lucas (date not recorded), which Mr. Belding gives as "very common in winter" south of latitude 24° 30′, and which Mr. Bryant reports as "tolerably common along the estero" north of Magdalena Bay and also "seen about fresh water at Comondu and San Pedro." Mr. Frazar noted a single bird at La Paz on March 21, and between September 19 and October 20 collected fourteen specimens at San José del Cabo, where, however, he did not meet with them in any great numbers. His latest record at this place is November 9, when two birds were observed.

Totanus flavipes (Gmel.).

Yellow-legs.

Although the Yellow-legs has not been previously recorded from any part of Lower California Mr. Frazar found it much more numerous than *T. melanoleucus frazari*. It was, however, observed only at San José del Cabo where it became common as early as August 28, but did not reach its maximum abundance until the middle of September, when upwards of two hundred were sometimes seen in the course of a single day. After September 20, its numbers rapidly diminished and the last bird was taken on October 7.

This Yellow-legs winters as far south as Patagonia and breeds in the Arctic and Subarctic portions of North America.

Helodromas solitarius (Wils.).

Solitary Sandpiper.

[*Totanus*] *solitarius* Brewster, Auk, VII. 1890, 378 (crit.; San José del Cabo).

An adult male Solitary Sandpiper (No. 17,739) taken by Mr. Frazar at San José del Cabo, on October 28, agrees perfectly in size as well as coloring with autumnal adults of this species from the Eastern States, and is apparently true *solitarius* which is probably a mere accidental wanderer to this region, for all the other specimens in the collection belong to the following subspecies. It is possible, however, that the bird just referred to is really an exceptionally small example of *cinnamomeus*, for the latter when in fully mature plumage does not appear to differ in respect to either color or markings from *solitarius*.

Helodromas solitarius cinnamomeus (Brewst.).

Western Solitary Sandpiper.

Totanus solitarius cinnamomeus Brewster, Auk, VII. 1890, 377, 378 (orig. descr.; type from San José del Cabo).

This form was found only at San José del Cabo where, between August 25 and September 2, seven specimens were taken. It is characterized in Mr. Frazar's notes as "not numerous" and it was not seen after September 28. Neither this nor the typical form has been detected elsewhere in Lower California.

H. solitarius is recorded from California and from South America as far south as Peru, but it is safe to assume that many if not most of the birds which migrate up and down the Pacific coast are really representatives of the present subspecies.

According to Mr. Grinnell *cinnamomeus* is the only form which occurs in Los Angeles county, California, where it is a "common migrant on the interior lowlands."[1] It probably does not breed anywhere to the southward of British Columbia.

Symphemia semipalmata inornata Brewst.

Western Willet.

Symphemia semipalmata (not *Scolopax semipalmata* Gmelin) Ridgway, Proc. U. S. Nat. Mus., V. 1883, 534, footnote (Cape Region). Belding, *Ibid.*, VI. 1883, 351 (s. of lat. 24° 30′).

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[1] Pub. II. Pasadena Acad. Sci., 1898, 17.

Symphemia semipalmata inornata BRYANT, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 273 (near La Paz).

My reference of the specimens taken by Mr. Frazar to this form is tentative and based largely on geographical considerations, for I confess that I am quite unable to find any characters which may be depended on to separate *inornata* from *semipalmata* when in the gray plumage. The difference in size is merely an average difference, and in winter the two birds appear to be colored precisely alike. It is, indeed, not impossible that both forms are represented in my series from the Cape Region, although certainly more probable that all the birds which visit the Peninsula, as well as those which occur in California, are *inornata*.

Mr. Frazar met with this Willet in winter at La Paz and in autumn at San José del Cabo, where the first individual was seen on September 6, the last on October 18. The birds were not numerous at either place, and only four specimens were taken.

Mr. Belding seems to have had a different experience, for he found Willets, which presumably belonged to this subspecies "very common in winter" south of latitude 24° 30′. Mr. Bryant speaks of seeing the Western Willet at Magdalena Bay in April (as late as the 28th) and he further states that "at San Quintin Bay Mr. Anthony noted them as abundant in winter, and a few were seen throughout the summer."

The Willet has a very extended range, occurring from about 56° N. latitude to the Pampas in South America. Neither the summer nor winter distribution of the subspecies *inornata* is at all definitely known, but it has been found in winter in the southern United States and it certainly breeds in Utah, Dakota, and other inland districts of North America. Mr. Grinnell reports that it is a "common migrant and occasional through the winter on the tide marshes along the coast" of Los Angeles county, California.[1]

Heteractitis incanus (GMEL.).

WANDERING TATLER.

Mr. Ridgway, in the Manual,[2] says that the adult of *H. incanus* in the winter plumage is "without any bars on lower parts," but two of Mr. Frazar's specimens, both taken on October 1 and otherwise in apparently full winter dress, have the middle of the breast, the abdomen, and the under tail coverts rather conspicuously and coarsely barred with slaty brown. A third, shot the same day, has the breast and sides similarly barred, but the middle of the abdomen and the under tail coverts are immaculate. As the barred feathers in all three birds are more or less worn and apparently remnants of the summer plumage, it is probable that they would have disappeared later in the season.

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[1] Pub. II. Pasadena Acad. Sci., 1898, 17.

[2] Man. N. Amer. Birds, 2d ed., 1896, 167.

The Wandering Tatler was of course to be expected in this region, for it is a common bird on the coast of California, and was found by Mr. Belding at Cerros Island,[1] while it has occurred as far to the southward as the Galapagos. Mr. Frazar, however, seems to have been the first to detect it in the region of which this paper especially treats. He met with it only twice, on October 1 and 22, both times on a rocky point that juts out into the sea near San José del Cabo. On the first occasion he saw nine birds, of which seven were secured. Their attitudes when standing on the rocks were like those of Oystercatchers, but their actions more nearly resembled those of the Spotted Sandpiper, although none of the "teetering" motions which are so characteristic of the latter were observed. During his second visit to this point only one bird was found.

Actitis macularia (Linn.).

Spotted Sandpiper.

Tringoides macularius Belding, Proc. U. S. Nat. Mus., V. 1883, 545 (Cape Region), 548 (San José).

Actitis macularia Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 273, (Cape Region).

On comparing fifteen specimens (all autumn birds) of this Sandpiper from the Cape Region with a large number of eastern examples I find that the bills of the former are almost invariably longer, although the other dimensions do not appear to be greater. In coloring, the Lower California birds are in no way peculiar. A male shot on September 1 has the entire abdomen, as well as the breast posteriorly, sparsely but coarsely spotted with dull black. Another male, taken on October 26, also shows a few fine dusky spots on the flanks and anal region. In both specimens the spotted feathers are fresh, unworn, and evidently a part of the winter plumage, although Mr. Ridgway describes this[2] as without spotting on the under parts.

Mr. Belding, in his list of birds seen on May 17, 1882, at San José del Cabo, characterizes the Spotted Sandpiper as "rare," but Mr. Frazar found it at this place in considerable numbers during the whole of September, and less numerously, but still rather frequently, in October, up to the 26th. He also noted it as "not rare" at Carmen Island on March 6, and his collection contains a bird taken at Triunfo on April 8. Mr. Bryant reports it from Magdalena Bay and Ensenada, and adds that "Mr. Anthony has seen it in the fall, and Mr. Belding May 12, at San Rafael."

The Spotted Sandpiper visits Central America and the northern portions of South America in winter, but it is not known to breed south of the United States. To the northward, along the Pacific coast, its summer range extends to Alaska.

[1] Proc. U. S. Nat. Mus., V. 1883, 532.

[2] Man. N. Amer. Birds, 2d ed., 1896, 170.

Numenius longirostris Wils.

Long-billed Curlew.

Numenius longirostris Belding, Proc. U. S. Nat. Mus., V. 1883, 545 (Cape Region). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 273 (Cape Region).

Mr. Frazar found the Long-billed Curlew at La Paz, where it was "common in February," and at San José del Cabo, whence he sent me several specimens collected late in August and early in September. Mr. Belding mentions it without comment in his list of birds seen in the winter and spring of 1881–82. Mr. Bryant considers it rare about Magdalena Bay, but says that further northward, according to Mr. Anthony, it is "very abundant along the coast in winter, and fairly swarming at San Quintin Bay."

The range of this species on the Pacific coast extends from Vancouver's Island to Guatemala. It breeds in the interior, not anywhere to the southward of California, so far as is known.

Numenius hudsonicus Lath.

Hudsonian Curlew.

Numenius hudsonicus Belding, Proc. U. S. Nat. Mus., V. 1883, 545 (Cape Region), 547 (San José del Cabo). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 274 (Cape Region).

This Curlew, according to Mr. Frazar, is more numerous in Lower California than the Long-billed species. Like the latter, it occurred in February and March at La Paz, and in the autumn at San José del Cabo, where the first (three birds) were seen on August 29, and the greatest number about September 15, after which they became scarce. Mr. Bryant reports them common at Magdalena Bay, and they have been observed at San Quintin Bay by Mr. Anthony.

The Hudsonian Curlew breeds only in the extreme northern portions of the American continent, but it migrates as far southward as Patagonia, and has been seen on the Galapagos. According to Mr. Grinnell, it is of common occurrence in Los Angeles county, California, during the migrations in spring and autumn.[1]

Squatarola squatarola (Linn.).

Black-bellied Plover.

Squatarola helvetica Belding, Proc. U. S. Nat. Mus., V. 1883, 545 (Cape Region).
Charadrius squatarola Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 274 (Cape Region).

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[1] Pub. II. Pasadena Acad. Sci., 1898, 18.

A few Black-bellied Plover were seen by Mr. Frazar at San José del Cabo, the first (two in number) on October 18, the last on November 9. They were rather common at Loreto and Carmen Island in March, at which season they are also found in small flocks on Santa Margarita Island, according to Mr. Bryant, while Mr. Belding has observed them as late as May 10, at San Quintin Bay.

Although this Plover is said to occur during the entire winter on the coast of California, it is known to migrate as far south as Peru. It breeds in the Arctic regions.

Charadrius dominicus Müll.

AMERICAN GOLDEN PLOVER.

Mr. Frazar killed an American Golden Plover at San José del Cabo on October 18, and thinks he saw a few others about the same time. His specimen, a young male (No. 17,656), in fresh autumn plumage, is typical *dominicus*. No form of the Golden Plover is known to have been taken before in any part of Lower California.

C. dominicus has occurred as far south as Chili on the Pacific coast. It is apparently a rare visitor to California, for Dr. Brewer states[1] that Dr. Cooper "has only seen a single specimen, shot near San Francisco by Mr. J. Hepburn." The Golden Plover is confined to the Arctic regions during the season of reproduction.

Aegialitis vocifera (Linn.).

KILLDEER.

Aegialitis vociferus Baird, Proc. Acad. Nat. Sci. Phila., 1859, 301, 306 (Cape St. Lucas).

Oxyechus vociferus Ridgway, Proc. U. S. Nat. Mus., V. 1883, 534, footnote (Cape St. Lucas). Belding, *Ibid.*, VI. 1883, 351 (s. of lat. 24° 30').

Aegialitis vocifera Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 274 (Cape Region; Cape St. Lucas).

The Killdeer is resident in the Cape Region. Mr. Frazar found it rather rare at La Paz in winter, but it was abundant about San José del Cabo through September, its numbers decreasing rapidly after October 1. On top of the Sierra de la Laguna some ten pairs were nesting early in May, and a few birds lingering as late as November 28. Throughout the northern and central portions of the Peninsula it is said to be common and very generally distributed. On San Pedro Martir it has been observed by Mr. Anthony as high as 9,000 feet altitude.

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[1] Baird, Brewer, and Ridgway, Water Birds N. Amer., I. 1884, 143.

This species visits various parts of northern South America in winter, and a few birds are supposed to breed in northern Mexico, but the majority doubtless nest north of the southern boundary of the United States.

Aegialitis semipalmata (Bonap.).

Semipalmated Plover.

Aegialitis semipalmata Belding, Proc. U. S. Nat. Mus., VI. 1883, 351 (s. of lat. 24° 30′). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 274 (near La Paz).

Mr. Frazar found this Plover common at La Paz in February, at Carmen Island in March, and at San José del Cabo from August 23 to the latter part of October. Mr. Belding notes it as "moderately common" south of latitude 24° 30′, and Mr. Bryant saw a flock of seven at Magdalena Bay on March 12, 1889, while Mr. Anthony reports it common at San Quintin Bay.

The Semipalmated Plover breeds in the Arctic and Subarctic regions, and on the west coast of America migrates as far south as Peru and Chili.

Aegialitis nivosa Cass.

Snowy Plover.

Aegialitis alexandrinus nivosus Belding, Proc. U. S. Nat. Mus., V. 1883, 545 (Cape Region).

Aegialitis nivosa Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 274 (Cape Region).

The numerous autumnal specimens of the Snowy Plover collected by Mr. Frazar show surprisingly little variation except in respect to size. The adult males are quite as ashy above as the young birds, from which they can be distinguished, however, by the much darker bars on the sides of their breasts and by the presence of a few black feathers on that part of the forehead occupied by a conspicuous black band in breeding males.

Mr. Frazar saw a small flock of Snowy Plover in March on the island of San José. He afterwards found them at San José del Cabo where they were common during September, October, and the first half of November, occurring usually in flocks of not more than six or eight birds, although fully thirty were seen together on one occasion. They were very tame, but when pursued attempted to elude observation by squatting in holes or depressions. At one time all the birds of the large flock just mentioned concealed themselves in footprints left by horses in the sand of the beach, showing only their heads above the level of the surrounding surface.

Mr. Belding makes only a nominal mention of this species in his papers relating to the Cape Region. To the northward Mr. Bryant has found it common in March on Santa Margarita Island, and it has been reported from Santa Rosalia Bay. On the Pacific coast the Snowy Plover is found from California to northern Chili, "and there is no evidence that it is a migratory bird in any part of its range."[1]

Aegialitis wilsonia (Ord).

Wilson's Plover.

Ochthodromus wilsonius Belding, Proc. U. S. Nat. Mus., V. 1883, 545 (Cape Region).

Aegialitis wilsonia Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 275 (Cape Region).

My Lower California specimens of Wilson's Plover have considerably less white on the forehead and sides of the head than do the birds from the eastern United States. In the latter the forehead and superciliary stripes are pure white and the lores often whitish. In the former the lores are always dusky, the superciliary stripe is usually narrow and sometimes indistinct, and the white of the forehead often more or less mixed with gray. The upper parts are a shade darker, and in the female the pectoral band is somewhat broader and duskier. In some of these respects the Lower California birds resemble Mr. Ridgway's well marked form *rufinucha*, or rather, to be more precise, they have even less white about the head than has that subspecies. In respect to the amount and depth of the rufous on the head and neck, however, they do not differ from typical *wilsonia*, to which, I think, they may best be referred.[2]

Mr. Frazar found Wilson's Plover "common at La Paz in February and at Carmen Island early in March." His collection also includes two specimens from San José del Cabo, taken respectively on October 18 and 22. The former date is referred to in his notes as that of the "arrival" of the species. In another connection he characterizes it as a "winter resident only." If it does not breed near Cape St. Lucas the question at once arises where the birds which occur there in winter come from, for none have been reported from any locality in the central or northern portions of the Peninsula. Mr. Seebohm says[3] that *A. wilsonia* breeds "as far north as California," but no authority is given for this statement. Baird, Brewer, and Ridgway limit[4] its northward range on the Pacific coast to Cape St. Lucas. Southward it occurs on the western shores of Mexico, Central America, and South America to the extreme northern part of Peru. Throughout this range it is said to breed wherever found.

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[1] Seebohm, Geogr. Distr. Charadriidae, 1888, 172.

[2] Since writing the above I find that Mr. Ridgway has called attention to some of these peculiarities as illustrated by specimens from Mazatlan and Cape St. Lucas in the collection of the National Museum (Baird, Brewer, and Ridgway, Water Birds, N. Amer., I. 1884, 169).

[3] Geogr. Distr. Charadriidae, 1888, 155.

[4] *Loc. cit.*, 168.

Arenaria morinella (Linn.).

Ruddy Turnstone.

All of the six Turnstones collected in Lower California by Mr. Frazar appear to be *morinella*. At least they are not larger than the birds found in eastern America, nor, so far as I can see, unlike them in respect to color or markings. No one of them is in fully mature plumage, even the two specimens which were taken in March being closely similar in coloring to the four young birds killed the following autumn. According to Dr. Palmer,[1] however, it is not difficult to distinguish immature specimens of *morinella* from those of *interpres*.

This Turnstone, now for the first time reported from the Cape Region, was found by Mr. Frazar at Carmen Island and San José del Cabo. At the former place it was common on March 12; at the latter a few were seen at various dates between August 31 and October 21. The collection includes specimens from both of these localities. Mr. Anthony has observed Turnstones belonging either to this form or to *interpres* in April, at San Ysidro, and Mr. Bryant has met with others, in February and March, 1888, on Magdalena Island and in March, 1889, on Santa Margarita Island. On the latter island Mr. Bryant has also found *Arenaria melanocephala*, a species which doubtless occasionally visits the Cape Region.

A. morinella is said to occur throughout "America from the Arctic regions north of Hudson Bay and westward to the Mackenzie River, along the Atlantic watershed, though generally coastwise, to Patagonia and the Falkland Islands." It "breeds about Hudson Bay, northward and eastward," and is at all seasons "rare on the Pacific slope." *A. interpres* ranges over the greater part of the Old World and breeds in Alaska and from Japan "westward around to the more northern British islands, Azores (?), and Greenland."[2]

Haematopus frazari Brewst.

Frazar's Oyster-catcher.

Haematopus palliatus (not of Temminck) Belding, Proc. U. S. Nat. Mus., VI. 1883, 351 (La Paz).

Haematopus frazari Brewster, Auk, V. 1888, 84, 85 (orig. descr.; type from Carmen Island). A. O. U. Comm., Suppl. to Check List, 1889, 7; Check List, abridged ed., 1889, and 2d ed., 1895, no. 286.1. Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 275, 276 (La Paz, etc.). Townsend, Proc. U. S. Nat.

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[1] Fur Seals and Fur Seal Islands N. Pacific Oc., pt. III. 1899, 408–418.

[2] Palmer, *Loc. cit.*, 408.

Mus., XIII. 1890, 138 (Concepcion Bay). Coues, Key N. Amer. Birds, 4th ed., 1894, 904, 905 (descr.; Lower Calif.). Ridgway, Man. N. Amer. Birds, 2d ed., 1896, 588 (descr.; Lower Calif., both coasts). Sharpe, Cat. Birds Brit. Mus., XXIV. 1896, 117 (descr.; Carmen Island), 730.

Haematopus fraseri (err. typ.), Elliot, N. Amer. Shore Birds, 1895, 210, 211, pl. 72 (descr.; habits; crit.; Gulf of Calif., n. of La Paz).

H.[aematopus] frazeri (err. typ.), Elliot, *Loc. cit.*, 252 (key to species).

[*Haematopus*] *frazari* Sharpe, Hand-list, I. 1899, 147.

Mr. Belding's statement that *H. palliatus* is "of occasional occurrence on the mud flats at La Paz" undoubtedly relates to this species, although the latter was found by Mr. Frazar only on the sandy islands and shores of the Gulf to the northward of the place just mentioned. It was particularly common on Carmen Island early in March, when all the birds seen were paired and evidently about to breed. There is a specimen in the National Museum which was taken by Mr. Belding at the Coronados Islands off the Pacific coast of Lower California "about twenty miles south and west of San Diego."

Mr. Bryant found *H. frazari* "tolerably common at Magdalena Bay and northward, and on Santa Margarita Island. They were mated in January. They were rather shy, running rapidly on the beach, and if approached, taking wing with loud, clear, whistling notes, and after flying some distance, alighting again at the water's edge. Their food was chiefly small bivalves found in the gravelly beach. Two birds were obtained, of one fragments only were saved."

It is a curious fact that *H. palliatus* is represented in the collection of the National Museum by apparently typical specimens from the western coasts of Mexico, Tehuantepec, Peru, and Chili, and that *H. frazari*, which is most closely allied to the Galapagos species (*H. galapagensis*), is known only from Lower California.

Haematopus bachmani Aud.

Black Oyster-catcher.

Haematopus bachmani Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 276 (La Paz).

Of this Oyster-catcher Mr. Bryant says: "A few were seen on Los Coronados Islands by Mr. Belding, also at San Quintin Bay and La Paz. Mr. Anthony has found them more common on the northwest coast than the preceding species [*H. frazari*]." The mention of La Paz in the above quotation constitutes, apparently, the only record of the occurrence of the bird in the Cape Region, which probably represents the extreme limit of its range southward. To the northward it is found nearly everywhere along the Pacific coast from California to the Aleutian Islands.

Lophortyx californicus vallicola (Ridgw.).

Valley Partridge.

Lophortyx californica (not *Tetrao californicus* Shaw) Baird, Proc. Acad. Nat. Sci. Phila., 1859, 301 (Cape St. Lucas). Belding, Proc. U. S. Nat. Mus., V. 1883, 544 (Cape Region), 547 (Pichalinque Bay).

Lophortyx californicus (not *Tetrao californicus* Shaw) Baird, *l. c.*, 305 (Cape St. Lucas). Baird, Brewer, and Ridgway, Hist. N. Amer. Birds, III. 1874, 482, part (breeding at Cape St. Lucas).

Callipepla californica vallicola Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 276 (Cape Region; Pichalinque Bay). Townsend, Proc. U. S. Nat. Mus., XIII. 1890, 136 (Cape St. Lucas). Bendire, Life Hist. N. Amer Birds, pt. I. 1892, 29 (descr. eggs from Cape St. Lucas).

The specimens collected by Mr. Frazar are slightly paler than my examples from California, and their bills average a little heavier, but these differences are neither well marked nor constant.

The Valley Partridge is very common, and of course resident, throughout the low country of the Cape Region. Mr. Frazar found it in the greatest numbers at Triunfo and San José del Rancho. About La Paz it was not numerous, and none were seen on the Sierra de la Laguna. The latter fact is somewhat remarkable, for on San Pedro Martir, in the northern part of Lower California, Mr. Anthony has met with large flocks at an altitude of 8,200 feet. Mr. Bryant mentions a nest containing thirteen eggs found at Calmalli on April 13, 1889. The bird is apparently generally distributed over the entire Peninsula, excepting, as just stated, on the high mountains south of La Paz. It also occurs in the interior of California, being replaced in the coast districts of that State by the typical form, *L. californicus*. Mr. Ridgway informs me that he was mistaken in stating (Proc. U. S. Nat. Mus., V. 1883, 533) that the Plumed Quail (*Oreortyx pictus plumiferus*) had been taken by Mr. Xantus at Cape St. Lucas, and that he knows of no good evidence to show that it has ever occurred in the Cape Region.

Columba fasciata vioscae Brewst.

Viosca's Pigeon.

Columba flavirostris Cooper, Orn. Cal., 1870, 508, part (Cape St. Lucas). Coues, Check List, 1873, 73, no. 368, part.

[Columba] flavirostris Coues, Key N. Amer. Birds, 1872, 225, part (Cape St. Lucas).

Columba fasciata (not of Say) Ridgway, Nom. N. Amer. Birds (Bull. U. S. Nat. Mus., no. 21), 1881, 40, no. 456, part; Proc. U. S Nat. Mus., V. 1883, 533, footnote (Cape St. Lucas; Miraflores). Coues, Check List, 2d ed., 1882, 91, no. 539, part. Belding, Proc. U. S. Nat. Mus., VI. 1883, 350 (Victoria Mts.). A. O. U., Check List, 1886, 178, 179, no. 312, part.

Columba fasciata vioscae Brewster, Auk, V. 1888, 86 (orig. descr.; type from La Laguna). A. O. U. Comm., Suppl. to Check List, 1889, 8; Check List, abridged ed., 1889, and 2d ed., 1895, no. 312 a. Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 277 (Cape St. Lucas; Miraflores; Victoria Mts.); Zoe, II. 1891, 198 (Victoria Mts.). Bendire, Life Hist. N. Amer. Birds, pt. I. 1892, 127, 128, pl. 3, fig. 18 (descr. nest and egg from near Pierce's Ranch, Lower Calif.). Coues, Key N. Amer. Birds, 4th ed., 1894, 904 (descr.; Lower Calif.). Ridgway, Man. N. Amer. Birds, 2d ed., 1896, 591 (descr.; s. portions of Lower Calif.).

Columba vioscae Salvadori, Cat. Birds Brit. Mus., XXI. 1893, 293, 294 (quotes orig. descr.; San José del Rancho; Lower Calif.).

[*Columba*] *vioscae* Sharpe, Hand-list, I. 1899, 70.

This Pigeon seems to be strictly confined to the Cape Region, for neither Mr. Bryant nor Mr. Anthony has succeeded in finding it in the central or northern portions of the Peninsula where true *fasciata* is also apparently wanting.

On reaching the summit of the Sierra de la Laguna, on April 26, 1887, Mr. Frazar saw his first Viosca's Pigeons. At this date they were not numerous, nor did they become so until May 15, when they began cooing. During the latter part of May they were abundant, although still in flocks, some of which contained upwards of fifty birds each. They continued to increase in numbers up to the date of Mr. Frazar's departure — June 9. A female taken on June 3 had apparently laid one egg and was certainly about to lay another. This was the only instance of breeding noted here. The people living in the neighborhood asserted that eggs were seldom found before August, and that the number in a nest varies from one to two.

At San José del Rancho Viosca's Pigeons were numerous in July, feeding greedily on wild grapes, which were ripe by the 5th of the month. The owner of this ranch said that the birds had first appeared there about the middle of May. They apparently did not begin breeding until the middle of July, when a nest containing one egg was reported by a hunter. Mr. Frazar visited this nest on July 22 and found it empty, but a broken egg was lying on the ground beneath. On the 27th a perfect egg was taken from the oviduct of a bird. By the last of July most of the Pigeons had left the neighborhood, "owing probably to the grapes having gone by."

At San José del Cabo large flocks were observed in September passing southward. Mr. Frazar believes that the majority left Lower California that season before winter set in, although he saw a few on November 15 along the road between San José and Miraflores and others at San José del Rancho, December 18–25. None were found on the Sierra de la Laguna between November 27 and December 2.

The note of this Pigeon seemed to Mr. Frazar "more the *hoo* of an Owl than the *coo* of a Dove. It is given twice, and is low and deep in tone. The birds fly in compact flocks but not as swiftly as the White-winged Doves."

Mr. Belding found[1] Viosca's Pigeon "abundant and breeding in February" in the "Victoria Mountains," but gives no definite localities. "Several nests were seen in oak trees, but not closely examined, however, they were so frail, twigs alone having been used in their construction. The eggs could be seen by looking through them from below. Their flesh was here excellent, notwithstanding they were subsisting principally upon the acorns of the deciduous oak (*Quercus grisea*)."

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[1] *Loc. cit.*

From this we must infer either that the eggs are laid at widely different dates at different localities or in different years, or that the nesting season extends over a period of more than six months in each year. The latter supposition seems the more reasonable in view of the fact that the breeding season of the Ground Dove in the Cape Region is known to cover fully half the year. The apparent migration of Viosca's Pigeons witnessed by Mr. Frazar was probably exceptional and due to a failure of the usual food supply.

The eggs taken by Mr. Frazar measure respectively: 1.53 × 1.09 and 1.48 × 1.04. They are elliptical ovate in shape, with rather rough, granulated shells of a dead, chalky white color.

Zenaidura macroura (Linn.).

Mourning Dove. Carolina Dove.

Zenaidura carolinensis Belding, Proc. U. S. Nat. Mus., V. 1883, 544 (Cape Region).
Zenaidura macroura Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 277 (Cape Region).
Mourning Dove Bryant, Zoe, II. 1891, 189 (San José del Cabo).

Mr. Frazar found Carolina Doves abundant on the Sierra de la Laguna in early May, when they were apparently migrating, for all had left the mountain before the end of the month. They were also seen in large numbers on August 23 about half way between Miraflores and San José del Cabo, and at the latter place they occurred sparingly during September. On December 3 a single bird was observed on the Sierra de la Laguna just below the lower limits of the pine belt, and the species was common at Triunfo during the last week of December. None were met with near La Paz, where, however, Mr. Belding found them "very abundant" in the winter of 1881–1882. Their presence or absence in any given locality at the latter season is doubtless determined chiefly if not wholly by the food supply.

In the central portions of Lower California, the Mourning Dove, according to Mr. Bryant, is common in March, but less so in April; still further northward Mr. Anthony has seen it in spring and autumn "from the coast to an altitude of 8,200 feet on La Grulla, but not very common anywhere" (Bryant) and at various seasons near San Fernando where it is nowhere abundant.[1] The only definite proof of its breeding on the Peninsula seems to be that furnished by Mr. Bryant's record of a nest containing two fresh eggs found at Comondu on April 15.

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[1] Anthony, Auk, XII. 1895, 137.

On the Pacific slope the Carolina Dove ranges from British Columbia to Panama.

Melopelia leucoptera (Linn.).

White-winged Dove.

Melopelia leucoptera Baird, Proc. Acad. Nat. Sci. Phila., 1859, 301, 305 (Cape St. Lucas). Baird, Brewer, and Ridgway, Hist. N. Amer. Birds, III. 1874, 378 (breeding at Cape St. Lucas). Belding, Proc. U. S. Nat. Mus., V. 883, 544 (Cape Region); VI. 1883, 350 (Victoria Mts.). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 277 (Cape Region; Victoria Mts.).

White-winged Dove Bryant, Zoe, II. 1891, 189 (San José del Cabo).

This Dove is abundant at all seasons over the entire Peninsula south of La Paz, breeding at every altitude from the sea-coast to the tops of the highest mountains. To the northward it extends at least as far as San Fernando (about latitude 30°), where, according to Mr. Anthony, it is rather common (Bryant). Mr. Frazar took fresh eggs at La Paz on March 24, and at Triunfo in April and again in June. On the Sierra de la Laguna the birds were mated in May, but apparently had not begun nesting at the date of Mr. Frazar's departure (June 9). A few were seen on the summit of this mountain in December.

The White-winged Dove occurs on or near the Pacific coast from Lower California and Arizona to Costa Rica.

Columbigallina passerina pallescens (Baird).

Mexican Ground Dove.

Chamaepelia var. *pallescens* Baird, Proc. Acad. Nat. Sci. Phila., 1859, 301 (Cape St. Lucas).

Chamaepelia passerina ? var. *pallescens* Baird, *Loc. cit.*, 305 (orig. descr.; types from Cape St. Lucas).

Chamaepelia passerina (not *Columba passerina* Linnaeus) Baird, Rept. Pac. R. R. Surv., IX. 1858, 606, 607 (La Paz, W. Hutton). Baird, Brewer, and Ridgway, Hist. N. Amer. Birds, III. 1874, 392, part (breeding at Cape St. Lucas from April 15 to Aug. 29).

Chamaepelia passerina, var. *pallescens* Cooper, Orn. Cal., 1870, 517, 518 (descr.; Cape St. Lucas).

Chamaepelia passerina pallescens Belding, Proc. U. S. Nat. Mus., V. 1883, 544 (Cape Region).

Columbigallina passerina pallescens Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 278 (Cape Region). Townsend, Proc. U. S. Nat. Mus., XIII. 1890, 137 (Cape

St. Lucas). **Bryant**, Zoe, II. 1891, 188, 189 (San José del Cabo). **Bendire**, Life Hist. N. Amer. Birds, pt. I. 1892, 150 (eggs taken near Cape St. Lucas by Xantus and at San José del Cabo by Belding).

This little Dove is resident in the Cape Region, where it appears to be quite as numerous and almost as widely distributed as the White-winged Dove. It is apparently uncommon among the higher mountains, however, for Mr. Frazar saw only one or two on the Sierra de la Laguna in spring and none during his visit in December. He met with it in the greatest numbers at San José del Cabo, where a nest containing two fresh eggs was found as late as October 18. As it was breeding at La Paz early in February and at most of the places visited during the spring and summer there would seem to be only three months in the year which are not included in its season of reproduction. A nest taken at Pierce's Ranch on July 19 was nearly flat, about four inches in width across the top, and composed chiefly of weed stalks. The two eggs which it contained are dead white in color and measure respectively: .86 × .64 and .82 × .64.

The Mexican Ground Dove is apparently not at all common in the parts of the Peninsula which Mr. Bryant visited, but more were seen about Comondu than elsewhere. The only specimen observed "on Santa Margarita Island was taken January 26, 1888, when it came to a tank for water."

The range of this Ground Dove extends along the Pacific coast from Lower California to Central America. The bird is also said to occur casually in California.

Cathartes aura (Linn.).

Turkey Vulture.

Cathartes aura **Belding**, Proc. U. S. Nat. Mus., V. 1883, 544 (Cape Region), 548 (San José); VI. 1883, 350 (Victoria Mts.). **Bryant**, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 278 (Cape Region).

Although no mention of the Turkey Vulture occurs in any of the papers relating to Xantus's experience, the bird at this day is found at all seasons throughout the southern extremity of Lower California, where, as well as nearly everywhere in the central and northern portions of the Peninsula, it is an abundant and familiar species.

> "They were common in Magdalena Island, frequenting the beach where cattle and turtles were slaughtered. On Santa Margarita Island I counted twenty, early one morning, perched on the tops of the giant cacti. The offal from a turtle killed at midday attracted fourteen buzzards in less than three hours. During an exceedingly hot day I saw a number of them gathered about a water-hole at Pozo Grande. Mr. Anthony says that they range in summer from sea-level to an altitude of 11,000 feet, but are confined to the sea-coast and lower hills in winter" (Bryant).

The single skin preserved by Mr. Frazar does not differ in any respect from more eastern and northern specimens.

The Turkey Vulture occurs along the Pacific coast from British Columbia to Patagonia.

Circus hudsonius (Linn.).

Marsh Hawk.

Circus hudsonius Belding, Proc. U. S. Nat. Mus., V. 1883, 544 (Cape Region). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 278 (Cape Region).

The Marsh Hawk apparently occurs in this region only in the character of a winter visitor, but it has been found breeding by Mr. Anthony at Cape Colnett and San Ramon in the northern part of the Peninsula. At San José del Cabo Mr. Frazar noted its arrival in autumn on September 5. It soon became common and continued so during October and November. During the latter month it was seen at Santiago, and early in December on the Sierra de la Laguna. At San José del Cabo Mr. Frazar found one of these Hawks devouring a Coot (Fulica) which it had evidently just captured, for the poor victim proved, on examination, to be still living.

The Marsh Hawk ranges south in winter to Panama and breeds from the southern border of the United States northward.

Accipiter velox (Wils.).

Sharp-shinned Hawk.

Accipiter fuscus Belding, Proc. U. S. Nat. Mus., V. 1883, 544 (Cape Region).
Accipiter velox Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 279 (Cape Region).

Of this species Mr. Frazar collected three representatives, two males and one female, all old birds in fine plumage. I am unable to find any differences whatever between these and eastern specimens.

Mr. Belding characterizes the Sharp-shinned Hawk as rare, but it was seen by Mr. Frazar on a number of occasions and at various places, from the sea-beach at San José del Cabo to the summit of the Sierra de la Laguna, the earliest date in autumn being October 31, the latest in spring some time in March. "Mr. Anthony gives it as resident of the region north of San Fernando [about latitude 30°], ranging as high as 4,000 feet altitude" (Bryant). Its general range extends as far south as the Isthmus of Panama and northward into Alaska.

Accipiter cooperii (Bonap.).

COOPER'S HAWK.

Accipiter cooperi Ridgway, Proc. U. S. Nat. Mus., V. 1883, 533, footnote (Cape St. Lucas; San Nicolas). Belding, *Ibid.*, VI. 1883, 351 (La Paz and s.). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 279 (Cape St. Lucas; La Paz).

The collection contains two specimens of this Hawk, a male and female, both immature. They belong to the dark, heavily streaked form that has been called *A. mexicanus.*

Cooper's Hawk was found by Mr. Frazar at much the same seasons and places as *A. velox.* It was commoner, however, and apparently less strictly a winter visitor, for it was seen at San José del Cabo as early as October 14 and on the Sierra de la Laguna as late as May 9, when a male in immature plumage was taken.

In the northern portions of the Peninsula Mr. Anthony has found Cooper's Hawk "common as high as 4,000 feet altitude until late in the spring," but he does not remember to have "seen it after the last of May" (Bryant). It breeds in California and northward into British Columbia and migrates southward to southern Mexico.

Parabuteo unicinctus harrisi (Aud.).

HARRIS'S HAWK.

Parabuteo unicinctus harrisi Belding, Proc. U. S. Nat. Mus., V. 1883, 544 (San José to Miraflores), 548 (San José). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 279 (San José del Cabo to Miraflores). Bendire, Life Hist. N. Amer. Birds, pt. I. 1892, 204 (San José del Cabo to Miraflores).

Harris's Hawk is apparently resident in the Cape Region. Mr. Belding met with it frequently along the road from San José del Cabo to Miraflores and noted it as common at the former place on May 17, 1882. Mr. Frazar found it most numerously at Triunfo; he saw very few at San José del Cabo and none on the Sierra de la Laguna. About La Paz it was decidedly rare. While staying at the house of Mr. Viosca, the American Consul at La Paz, Mr. Frazar had an interesting experience with a bird of this species. It came into the yard — which was filled with trees and bounded on three sides by buildings, on the fourth side by a fence, the total space enclosed being about thirty yards square — and began splashing about in an oval water tank, making frantic attempts to catch some of the numerous gold fish confined therein. The fish, however, concealed themselves among the rocks on the bottom, and the Hawk was shot before it had done any damage. Its plumage was thoroughly watersoaked, its body very thin, indicating that it had been made desperate by starvation.

Mr. Belding has seen Harris's Hawk about forty miles south of San Diego, California, and hence very near the northern boundary of the Peninsula. Mr. Bryant has observed it at San Jorge, near San Juan, and at San Gregoria. At the place last named he found a nest on April 6, 1889, built in the top of a bush (*Atamisquea emarginata*) and containing two eggs, "one of them quite fresh, the other with a small embryo."[1]

Mr. Anthony states that a few birds of this species nested in 1894 near San Fernando, "in cirios between the mine and the beach,"[2] and that during the previous year others were seen in valleys "between Ensenada and Colnett, and in one or two places on San Pedro [Martir] as high as 7000 feet."[3]

The general range of Harris's Hawk on or near the Pacific coast extends from northern Lower California to Panama.

Buteo borealis calurus (Cass.).

Western Red-tail.

B.[uteo] lucasanus Ridgway, in Coues, Key N. Amer. Birds, 1872, 216 (nominal mention only under *B. borealis;* Cape St. Lucas).

[*Buteo borealis*] var. *lucasanus* Ridgway, in Baird, Brewer, and Ridgway, Hist. N. Amer. Birds, III. 1874, 258 (key to species), 285, 286 (orig. descr.; type from Cape St. Lucas).

Buteo borealis calurus Belding, Proc. U. S. Nat. Mus., V. 1883, 544 (Cape Region); VI. 1883, 350 (Victoria Mts.). Ridgway, *Ibid.*, V. 1883, 544 (crit.; Cape Region). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 280 (Cape Region).

Buteo borealis lucasanus Bryant, *Loc. cit.* (name only). Palmer, Auk, XIII. 1896, 342 (note on proper citation). Bendire, Life Hist. N. Amer. Birds, pt. I. 1892, 217 (crit.; Cape St. Lucas).

Buteo borealis Godman and Sharpe, Biol. Centr.-Amer., Aves, III. 1900, 63, 64, part (crit.; Cape St. Lucas).

The determination of the Red-tailed Hawks collected by Mr. Frazar in Lower California has proved somewhat difficult, for they vary exceedingly in color and markings. In fact I found it impossible to come to any satisfactory conclusion regarding them until, thanks to the kindness of Mr. Ridgway and Dr. Allen, I was able to compare them with the material in the U. S. National Museum and in the American Museum of New York. This includes the type of *Buteo borealis lucasanus* as well as four other specimens referred to that form by Mr. Ridgway; three specimens each, including the types, of *Buteo borealis socorroensis* and *B. b. costaricensis;* and a superb series of *B. b. calurus,* containing a considerable number of specimens taken in Arizona by Dr. Mearns and now belonging to the American Museum. In addition my own collection has supplied some thirteen specimens of *calurus* from various parts of the western United States.

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[1] Proc. Calif. Acad. Sci., 2d ser., II. 1889, 279, 280.

[2] Auk, XII. 1895, 137.

[3] Zoe, IV. 1893, 233.

On examining Mr. Frazar's birds, twenty-eight in number, in connection with this material I have become convinced that so far as color and markings are concerned they cannot be separated from *calurus*, for every one of them may be closely matched by one or more of the specimens from Arizona, Colorado, or California; while even as series the birds of the two regions show no obvious differences except in size, those from the United States averaging slightly larger than those obtained in Lower California by Mr. Frazar.

Buteo borealis var. *lucasanus* was originally described by Mr. Ridgway[1] as differing from *B. calurus* in having "the upper parts more uniformly blackish, and the upper tail-coverts and tail uniform rufous, the latter without a trace of a black bar."[2]

On examining the tail of the specimen (No. 16,925 Smith. Cat., Cape St. Lucas, Sept. 15, 1859; J. Xantus) from which this description was taken I find, however, very decided indications of a dark subterminal band. This is represented by a transverse series of short, narrow, blackish bars more or less broken and confused, mainly confined to the inner webs of the feathers and in no instance continuous across both webs. The black is rather faint on most of the feathers, but on some of the inner ones is perfectly distinct, and on one of them is really sharply defined and very conspicuous, forming a solid bar, .15 of an inch in width, which extends from the shaft of the feather three quarters of the distance across its inner web. Of the outer pair of feathers one is apparently without any dark color near its tip, but both, as well as all the other rectrices, have a varying number of rather large black spots on one or both webs near the shafts, towards their bases. The tail of the type specimen (No. 17,212 Smith. Cat., San Nicolas, Oct. 1859; J. Xantus) lacks all trace of these basal spots and at first glance appears to be perfectly plain towards the tip, also, but close inspection under a strong light reveals innumerable minute, dusky spots which, when the tail is spread, prove to be arranged in a regular transverse series forming a faint, but unmistakable subterminal band. The other three specimens labeled by Mr. Ridgway as *B. lucasanus* are immature and do not differ from *calurus* in corresponding plumage.

The majority of Mr. Frazar's birds possess tail-bands quite as well-defined and conspicuous as in typical *calurus*, but in several of them the black is more or less broken and indistinct while at least two have the band scarce better marked than in the Smithsonian specimen, No. 16,925. With this specimen they furnish a nicely graduated series connecting those most heavily barred with the nearly plain-tailed type of *lucasanus*. As the Arizona specimens of *calurus* show quite as wide a range of variation with respect to the tail markings as do Mr. Frazar's birds, and as none of the other characters originally ascribed to *lucasanus* prove more satisfactory or constant, it is evident that the type of this supposed subspecies represents a mere accidental or extreme variation of a form which, as already stated, does not normally differ in either color or markings from *Buteo borealis calurus* of the western United States. In other words, all the Red-tailed Hawks thus far found in the St. Lucas Region are one and the same thing, and if they are to be separated from *calurus* — in which case they must bear the name *lucasanus* — it must be by size alone. The difference in this respect is so trifling that I cannot think it worth special recognition.

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[1] Baird, Brewer, and Ridgway, Hist. N. Amer. Birds, III. 1874, 285.

[2] In the Manual N. Amer. Birds, 2d ed., 1896, 233 Mr. Ridgway apparently abandons all of these characters except that of the color of the tail. In another connection (Proc. U. S. Nat. Mus., V. 1883, 544) he has expressed doubts as to whether the "principal character assigned to '*lucasanus*' (the uniform rufous tail without subterminal black bar) will prove constant, even in birds from the cape."

None of the Lower California or Arizona specimens resemble at all closely *B. b. socorroensis*, but I have two adult birds (No. 26,206, Jan. 8, 1887 and No. 26,207 Feb. 16, 1888) taken at Nicasio, California, by Mr. C. A. Allen, which differ from this form, as represented by the three U. S. Nat. Museum examples before me, only in having somewhat more black on the jugulum and throat and in being slightly larger. Another specimen (No. 24,780) in my collection from Alamos, western Mexico, is generally similar, but has more black spotting on the abdomen, and the breast and thighs are deeper colored. I see no alternative but to refer both this and the two Nicasio specimens to *socorroensis*. Such reference need not be prejudicial to the subspecific standing of the latter, for there is no reason why this bird, even if confined to Socorro Island during the breeding season, should not wander, at other times of the year, as far as Alamos, or even Nicasio.

B. costaricensis differs so very widely in coloring from any of the phases of *calurus* as not to require comparison in this connection.

In the following tables of measurements no birds not fully adult (*i. e.* red-tailed) are included: —

Buteo borealis socorroensis Ridgw.

No.	Sex	Locality	Date	Wing	Tail	Tarsus	Middle Toe	Culmen from Base	Culmen from Feathers	Culmen from Nostril	Depth of Bill at Nostril
117,499[1]	♂	Socorro Isl., Mex.	Mar. 8, '89	15.70	8.63	3.50	1.65	1.56	1.33	.85	.78
50,761[1]	♂	" " "	— — —	14.94	8.47	3.54	1.67	1.42	1.32	.85	.77
26,207[2]	♂	Nicasio, Cal.	Feb. 16, '88	16.72	9.20	3.73	1.70	1.56	1.34	.91	.72
24,780[2]	♂	Alamos, Mex.	Mar. 8, '88	16.31	9.06	3.67	1.67	1.55	1.26	.90	.80
26,206[2]	♂	Nicasio, Cal.	Jan. 8, '87	16.02	8.90	3.54	1.70	1.70	1.38	.92	.77
			Average,	15.94–	8.85+	3.59+	1.68–	1.56–	1.33–	.89–	.77–
117,500[1]	♀	Socorro Isl., Mex.	Mar. 8, '89	16.76	9.53	3.80	1.95	1.73	1.43	1.03	.90

[1] Collection U. S. Nat. Museum. Type, 50,761.

[2] Collection William Brewster.

Buteo borealis lucasanus Ridgw.

No.	Sex	Locality	Date	Wing	Tail	Tarsus	Middle Toe	Culmen from Base	Culmen from Feathers	Culmen from Nostril	Depth of Bill at Nostril
		Lower California.									
17,843[1]	♂	Sierra de la Laguna	Nov. 29, '87	15.90	8.97	3.52	1.60	1.50	1.35	.90	.70
17,841[1]	♂	“ “ “ “	May 28, '87	15.25	8.70	3.47	1.45	1.46	1.31	.87	.72
17,844[1]	♂	“ “ “ “	Dec. 2, '87	15.14	8.35	3.38	1.70	1.50	1.35	.91	.72
17,840[1]	♂	“ “ “ “	May 17, '87	15.06	8.46	3.32	1.67	1.45	1.32	.91	.70
17,842[1]	♂	“ “ “ “	May 28, '87	15.01	8.48	3.47	1.59	1.43	1.30	.90	.72
17,839[1]	♂	“ “ “ “	Apr. 27, '87	14.82	8.48	3.33	1.50	1.43	1.30	.86	.69
17,831[1]	♂	Santiago	Nov. 17, '87	16.08	9.32	3.52	1.76	1.50	1.26	.86	.75
17,832[1]	♂	Santiago	Nov. 24, '87	15.20	9.18	3.39	1.74	1.45	1.31	.85	.72
17,824[1]	♂	San José del Cabo	Nov. 3, '87	15.63	8.63	3.42	1.73	1.45	1.34	.91	.77
17,826[1]	♂	La Paz	Feb. 18, '87	15.27	8.21	3.54	1.77	1.47	1.34	.83	.72
17,825[1]	♂	La Paz	Feb. 9, '87	14.83	8.25	3.30	1.66	1.47	1.30	.87	.73
17,212[2]	♂	San Nicolas	Oct. —, '59	16.24	8.81	3.78	1.79	1.65	1.35	.98	.80
16,925[2]	♂	Cape St. Lucas	Sept. 15, '59	15.78	9.10	3.75	1.78	1.67	1.38	1.00	.83
			Average,	15.40+	8.69−	3.47−	1.67+	1.49+	1.32+	.90−	.74−
17,835[1]	♀	Santiago	Nov. 19, '87	16.93	10.03	3.25	1.81	1.70	1.40	.98	.77
17,837[1]	♀	Santiago	Nov. 26, '87	16.79	9.94	3.62	1.75	1.62	1.37	.99	.79
17,833[1]	♀	Santiago	Nov. 16, '87	16.35	9.52	3.87	1.90	1.65	1.48	1.02	.83
17,822[1]	♀	San José del Cabo	Nov. 3, '87	16.41	9.03	3.57	1.85	1.64	1.52	1.05	.77
17,823[1]	♀	San José del Cabo	Nov. 11, '87	16.20	9.32	3.79	1.75	1.67	1.52	.95	.78
17,827[1]	♀	La Paz	Feb. 9, '87	16.06	8.63	3.30	1.74	1.52	1.30	.93	.72
17,828[1]	♀	La Paz	Feb. 24, '87	15.52	8.82	3.33	1.77	1.62	1.42	.91	73
17,829[1]	♀	Triunfo	June 21, '87	15.90	8.79	3.32	1.72	1.56	1.45	.95	.75
			Average	16.27	9.26	3.51−	1.79−	1.62+	1.43+	.97+	.77−

Buteo borealis calurus (Cass.).

No.	Sex	Locality	Date	Wing	Tail	Tarsus	Middle Toe	Culmen from Base	Culmen from Feathers	Culmen from Nostril	Depth of Bill at Nostril
		Arizona.									
51,582[3]	♂	Fort Verde	Jan. 16, '87	16.06	9.07	3.58	1.81	1.54	1.36	.93	.73
51,584[3]	♂	“ “	Mar. 31, '87	15.90	9.17	3.68	1.75	1.60	1.35	.94	.80
51,571[3]	♂	“ “	Mar. 12, '86	15.75	8.97	3.33	1.60	1.52	1.35	.93	.80
51,577[3]	♂	“ “	Dec. 13, '86	15.52	9.25	3.55	1.62	1.45	1.36	.92	.75
51,573[3]	♂	“ “	Dec. 1, '86	15.45	8.61	3.70	1.62	1.48	1.24	.87	.73
51,590[3]	♂	Payson	Feb. 10, '88	16.05	9.15	3 68	1.70	1.52	1.35	.85	.75
51,580[3]	♂	Oak Creek	Jan. 6, '87	15.63	8.77	3 51	1.72	1.50	1.30	.85	.75
51,555[3]	♂	Ash Creek	Sept. 25, '84	15.62	9.92	3.70	1.67	1.52	1.36	.89	.80
51,556[3]	♂	Pine Springs	Nov. 17, '84	15.52	8.76	3.43	1.58	1.47	1.32	.90	.76
			Average,	15.72+	9.07+	3.57+	1.67+	1.51+	1.33+	.90−	.76+

[1] Collection William Brewster.

[2] Collection U. S. Nat. Museum. Type, 17,212.

[3] Collection Amer. Mus. Nat. Hist.

No.	Sex	Locality	Date	Wing	Tail	Tarsus	Middle Toe	Culmen from Base	Culmen from Feathers	Culmen from Nostril	Depth of Bill at Nostril
		Arizona.									
51,559[1]	♀	Fort Verde	Mar. 14, '85	17.80	9.75	3.62	1.67	1.71	1.44	.98	.78
51,574[1]	♀	" "	Dec. 11, '86	17.04	9.54	3.87	2.02	1.72	1.55	1.10	.85
51,561[1]	♀	" "	Mar. 25, '85	16.85	9.55	3.91	1.83	1.54	1.42	.98	.80
51,583[1]	♀	" "	Mar. 31, '87	16.85	9.53	3.73	1.82	1.65	1.43	.98	.85
51,558[1]	♀	" "	Jan. 10, '85	16.68	9.63	3.85	1.83	1.58	1.35	1.00	.79
51,589[1]	♀	Baker's Butte	July 17, '87	17.19	9.75	3.44	1.76	1.56	1.45	1.00	.80
51,579[1]	♀	Oak Creek	Jan. 6, '87	16.95	9.23	3.87	1.76	1.64	1.40	1.00	.77
51,554[1]	♀	Mogollon Mts.	Oct. 5, '84	16.77	9.75	3.60	1.71	1.50	1.30	.92	.75
51,560[1]	♀	Yarapai Co.	Mar. 25, '85	16.68	9.50	3.57	1.83	1.60	1.26	1.00	.78
51,586[1]	♀	Upper Verde Valley	Apr. 16, '87	16.28	9.46	3.76	1.82	1.62	1.42	.96	.82
			Average,	16.91–	9.57–	3.72+	1.81–	1.61+	1.40+	.99+	.80–

The Western Red-tailed Hawk is common and very generally distributed throughout the Cape Region. Mr. Frazar found it at all seasons, but most numerously in late autumn, when there is probably an influx of birds which have bred further north. During the last two weeks of November a great many were seen about the lagoon at Santiago, where they were evidently attracted by the Coots (Fulica), on which they were preying. Some of them were very bold and easily shot. One pounced on a Quail (*Lophortyx californicus vallicola*) which Mr. Frazar had just wounded and which lay fluttering on the ground within fifteen yards of the spot where he was standing.

Mr. Bryant saw the Western Red-tail at Santa Margarita Island in January and February, 1888; at Ubi on May 9, 1889; and at San Fernando (no date given). Mr. Anthony says that it is "very common throughout the northern part of the peninsula," and that he found it "nesting in abundance in the pines on San Pedro [Martir]."[2] Its general range along the Pacific slope extends from Alaska southward into Mexico.

Buteo abbreviatus Cab.

Zone-tailed Hawk.

Buteo abbreviatus Belding, Proc. U. S. Nat. Mus., V. 1883, 544 (Cape Region). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 280 (Cape Region). Bendire, Life Hist. N. Amer. Birds, pt. I. 1892, 229 (Cape St. Lucas Region). Godman and Sharpe, Biol. Centr.-Amer., Aves, III. 1900, 60 (nesting near Cape St. Lucas).

Mr. Belding mentions this species as "very rare." Mr. Frazar obtained no specimens, but on four different occasions at San José del Cabo, and once at Santiago he saw "a perfectly black Hawk having a narrow white band across the middle of the tail, and perhaps some white on the under tail coverts. It flew exactly like a Turkey Buzzard, its wings held at an upward slant." This bird, he thinks, must have been a Zone-tailed Hawk. On April 24, 1889, Mr. Anthony found two pairs nesting on San Pedro Martir, "at elevations of 7000 and 7500 feet," and one of the birds was secured.[1]

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[1] Collection Amer. Mus. Nat. Hist.

[2] Zoe, IV. 1893, 233.

B. abbreviatus has occurred in southern California a little north of San Diego, and is common in southern Arizona and thence southward through Mexico and Central America into northern South America.

Archibuteo ferrugineus (Licht.).

Ferruginous Rough-leg.

On November 28 Mr. Frazar obtained two Ferruginous Rough-legs on the summit of the Sierra de la Laguna. One he shot; the other had been killed the day before by a hunter, who claimed to know the bird perfectly well, and who asserted that it occurs regularly on this mountain in winter. Mr. Frazar did not hear of it elsewhere, and it does not seem to have been reported from any other part of the Peninsula, although it is common in California. The Cape Region perhaps represents the extreme southern limit of its wanderings on the Pacific coast.

Haliaeetus leucocephalus (Linn.).

Bald Eagle.

This Eagle must be rare in Lower California, for it has not been previously reported from any part of the Peninsula. Mr. Frazar, however, obtained definite proof not only of its presence, but of its breeding in the Cape Region, for he was shown a young captive bird in the possession of Mr. Viosca, the American Consul at La Paz, which that gentleman assured him had been taken from a nest on Espiritu Santo Island two years before. It was in the brown plumage when first examined (in January, 1887), but eleven months later exhibited some white on the head and tail. Mr. Frazar also saw a nest on the Gulf coast of the Peninsula opposite Carmen Island, which was evidently not an Osprey's, and which the people living in the neighborhood asserted had been occupied for several years by a pair of Eagles.

The Bald Eagle is found throughout California to the extreme southern border of the State. Dr. Brewer states[2] that it ranges as far south as Central America, but gives no specific records of its occurrence south of the southern border of the United States.

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[1] Zoe, IV. 1893, 234.

[2] Baird, Brewer, and Ridgway, Hist. N. Amer. Birds, III. 1874, 329.

Falco mexicanus Schleg.

PRAIRIE FALCON.

Hierofalco mexicanus Belding, Proc. U. S. Nat. Mus., V. 1883, 533, footnote (Miraflores; Cape St. Lucas; San José del Cabo).

Falco mexicanus Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 281 (Miraflores; Cape St. Lucas; San José del Cabo).

According to Mr. Ridgway, this Falcon was taken by Xantus at "Miraflores November 25; Cape Saint Lucas, December 14; San José del Cabo, December, January." It was not met with by Mr. Belding, nor certainly identified by Mr. Frazar. Mr. Bryant saw a pair about a cliff at Comondu in 1888, a single bird on Santa Margarita Island on March 2, 1889, and "a pair nesting in a high cliff" at San Esteban on April 18, 1889. The Prairie Falcon breeds rather commonly in California and Oregon, and ranges south into Mexico.

Falco peregrinus anatum (Bonap.).

DUCK HAWK.

Mr. Frazar, who seems to have been the first to meet with the Duck Hawk in the Cape Region, saw a few birds in February and March at La Paz (where one specimen, an adult female, was obtained) and others, in October and November, at San José del Cabo and Santiago. In the northern part of Lower California the species has been "found nesting in the cliffs along the coast at several places from San Carlos landing to San Quintin by Mr. Anthony, who says they are more common in winter" (Bryant).

The Duck Hawk inhabits the entire continent of America wherever the local conditions are suited to its requirements.

Falco columbarius Linn.

PIGEON HAWK.

Aesalon columbarius Belding, Proc. U. S. Nat. Mus., VI. 1883, 351 (La Paz).

Falco columbarius Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 281 (La Paz).

Several Pigeon Hawks were seen in autumn at San José del Cabo and Santiago by Mr. Frazar, the earliest date of observation being September 17, the latest November 17. The collection contains a typical specimen from each of these localities. Mr. Belding has reported the capture of a bird at La Paz in January, 1883. The species was not met with by either Mr. Bryant or Mr. Anthony. It ranges southward in winter to northern South America, and breeds chiefly north of the United States.

Falco columbarius richardsonii (RIDGW.).

RICHARDSON'S MERLIN.

An adult male Merlin (No. 17,872) in full autumn plumage, taken by Mr. Frazar at San José del Cabo, on October 31, is apparently referable to *richardsonii*, although it is far from typical, being quite as deeply colored as are light specimens of *columbarius*, and, like that species, having the outer webs of the outer two primaries perfectly plain. The remaining primaries, however, are conspicuously spotted on their outer webs, but the markings are bluish gray, of about the same shade as the mantle, instead of nearly white, as in *richardsonii*. The tail has five light and five dark bands, counting the terminal (light) and subterminal (dark) ones. This specimen is almost perfectly matched by another in my collection, of corresponding age and sex, from Larimer County, Colorado. It is difficult to see how such birds can be regarded other than as intermediate, and hence connecting, links between *richardsonii* and *columbarius*. Although Richardson's Merlin is chiefly confined to the interior districts of North America, it has been occasionally taken in California.

Falco sparverius deserticolus MEARNS.

DESERT SPARROW HAWK.

(?) *Tinnunculus sparverius* (not *Falco sparverius* LINNAEUS) BELDING, Proc. U. S. Nat. Mus., V. 1883, 543 (Cape Region); VI. 1883, 350, part (Victoria Mts.)

(?) *Falco sparverius* (not of LINNAEUS) BRYANT, Proc. Calif. Acad. Sci, 2d ser., II. 1889, 281, part (Cape Region).

Among the Sparrow Hawks sent me from the Cape Region by Mr. Frazar are four females, which are not only much larger than any of the others, but quite equal in size to average specimens of *deserticolus*, to which I refer them without hesitation. Three of these birds were obtained at San José del Cabo on September 17, October 19 and October 31, respectively, while the fourth was taken at Triunfo on December 22. From this we may infer that the form *deserticolus* is of not uncommon occurrence in the Cape Region in autumn and winter. Its general range includes practically the whole of the western United States, and extends from British Columbia to Mazatlan in northwestern Mexico.

Falco sparverius peninsularis MEARNS.

ST. LUCAS SPARROW HAWK.

Tinnunculus sparverius (not *Falco sparverius* LINNAEUS) BAIRD, Cat. N. Amer. Birds, 1859, no. 13, part; Proc. Acad. Nat. Sci. Phila., 1859, 301, 302 (Cape St. Lucas). (?) BELDING, Proc. U. S. Nat. Mus., V. 1883, 543 (Cape Region); VI. 1883, 350, part (Victoria Mts.).

Falco sparverius BAIRD, Rept. Pac. R. R. Surv., IX. 1858, 13, 14, part. COUES, Check List, 1873, 69, no. 346, part; 2d ed., 1882, 87, no. 508, part. BAIRD, BREWER, and RIDGWAY, Hist. N. Amer. Birds, III. 1874, 169–171, part. A. O. U., Check List, 1886, 196, no. 360, part. (?) BRYANT, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 281, 282, part (Cape Region, etc.).

[*Tinnunculus*] *sparverius* GRAY, Hand-list, I. 1869, 23, no. 216, part.

[*Falco*] *sparverius* COUES, Key N. Amer. Birds, 1872, 214, 215, part.

Cerchneis sparveria SHARPE, Cat. Brit. Birds, I. 1874, 437–439, part.

Tinnunculus sparverius RIDGWAY, Nom. N. Amer. Birds (Bull. U. S. Nat. Mus., no. 21), 1881, 38, no. 420, part.

Falco sparverius peninsularis MEARNS, Auk, IX. 1892, 267 (orig. descr.; type from San José). A. O. U. COMM., Auk, X. 1893, 60, no. 360 b; Check List, 2d ed., 1895, 140, no. 360 b.

F.[*alco*] *sparverius* RIDGWAY, Man. N. Amer. Birds, 2d ed., 1896, 252, part.

[*Cerchneis*] *peninsularis* SHARPE, Hand-list, I. 1899, 278.

The characters by which Dr. Mearns has proposed to distinguish *Falco sparverius peninsularis* are presented very constantly by twelve of the Sparrow Hawks collected by Mr. Frazar. Among these are an adult male taken at Triunfo on April 20, another in excessively worn breeding plumage shot at San José del Rancho on July 8, and a young male, just from the nest and barely large enough to fly, which was captured at the place last named on July 17. Eight of the remaining specimens were obtained in the Cape Region (at Triunfo, Santiago, or San José del Cabo) in October, November, or December, while the ninth was shot at Carmen Island on March 2.

This small, light-colored form of the Sparrow Hawk is of common occurrence in the Cape Region in autumn and winter, but it does not appear to breed there at all numerously, for Mr. Frazar met with it in summer only at San José del Rancho where he notes it as "very rare." It is believed to be confined to Lower California, but we have no definite knowledge as to just how far up the Peninsula its distribution extends. Mr. Bryant reports that he met with *Falco sparverius* "on Santa Margarita Island, Magdalena Island, Guadalupe Island, and several places" in Lower California; he also states that Mr. Anthony found it "common in summer along the base of San Pedro Martir, ranging in May to 9,000 feet altitude, and only seen on the coast during winter." These records relate of course either to *peninsularis* or *deserticolus* — or both — but at the time they were published neither of the forms just mentioned had been described.

Polyborus cheriway (JACQ.).

AUDUBON'S CARACARA.

Polyborus cheriway BELDING, Proc. U. S. Nat. Mus., V. 1883, 543 (Cape Region), 547 (San José). BRYANT, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 282 (Cape Region, Cape St. Lucas). BENDIRE, Life Hist. N. Amer. Birds, pt. I. 1892, 318 (descr. egg from Cape St. Lucas).

The Caracara is a resident species and is generally distributed and abundant, especially in the low country bordering the Gulf. Mr. Frazar notes it as paired and apparently breeding in January at La Paz, but he saw no nests until July 26, when one containing two chicks only a few hours old was found at San José del Rancho. On November 4, at San José del Cabo, he saw two Caracaras swoop at a slightly wounded Coot (Fulica) which was fluttering over a mud flat. Alighting they pursued it on foot, but although they evidently tried their best to overtake and capture it, it finally got to the water, when they gave up the chase and, after watching it awhile, flew off.

Mr. Bryant says that this species is "not often seen north of latitude 26°," but "two were said to have hung around a beach camp at Santo Domingo, on San Sebastian Viscaino Bay, north of lat. 28°." This probably represents about the extreme northern limit of the Caracara's range on the Pacific coast. To the southward it is found as far as Darien.

Pandion haliaëtus carolinensis (Gmel.).

AMERICAN OSPREY.

Pandion haliaëtus carolinensis Belding, Proc. U. S. Nat. Mus., V. 1883, 543 (Cape Region), 547 (San José). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 283 (Cape Region). Bendire, Life Hist. N. Amer. Birds, pt. I. 1892, 324 (measurements of egg from Cape St. Lucas, largest of 69 specimens, 68.5 by 49.5 mm.).

The Osprey is apparently resident and about equally numerous at all seasons, in the Cape Region. Mr. Frazar found a nest on Carmen Island, early in March, which contained a single freshly laid egg.

On Santa Margarita Island Mr. Bryant "counted a dozen nests, January 19, 1888, upon five of which were one or two birds," but the "nests upon which the birds were seen" on the date just mentioned "were without eggs on February 18," although two fresh eggs were taken on this island on January 25.

In the northern part of the Peninsula Mr. Anthony considers this species "abundant on all of the coast islands, and of less common occurrence along the coast" itself (Bryant).

The range of the Osprey on the Pacific coast extends from Panama to Alaska. It is known to breed as far south as the Tres Marias Islands.

Strix pratincola Bonap.

AMERICAN BARN OWL.

Aluco flammeus americanus Ridgway, Proc. U. S. Nat. Mus., V. 1883, 533, footnote (San José del Cabo; Caduana).

Strix pratincola Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 283 (San José del Cabo; Caduana).

According to Mr. Ridgway, the Barn Owl was found by Mr. Xantus at San José del Cabo in December and January, and at Caduana in November. Mr. Belding does not mention it in any of his lists, nor was it actually taken by Mr. Frazar, but the latter obtained a number of its wing and tail feathers on the Sierra de la Laguna. Mr. Bryant heard the bird at Magdalena and again near San Quintin, and Mr. Anthony reports it as "common in the northwestern part of the territory, up to an altitude of 3,500 feet, inhabiting old mines" (Bryant).

On the Pacific coast the Barn Owl ranges from California to southern Mexico. It is apparently locally resident wherever found.

Asio accipitrinus (Pall.).

SHORT-EARED OWL.

Asio accipitrinus Ridgway, Proc. U. S. Nat. Mus., V. 1883, 533, footnote (Miraflores); Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 284 (Miraflores).

The only record of the occurrence of this species in the Cape Region seems to be that given by Mr. Ridgway of a specimen[1] taken by Xantus at Miraflores on November 25. In the upper portion of the Peninsula Mr. Anthony has found it "along the coast region, north of San Fernando, in winter, and has frequently flushed . . . scattered companies of six to ten, from the salt grass about the bays. He has not seen them above 800 feet elevation" (Bryant).

The Short-eared Owl, at one season or another, visits nearly every part of the American continent, for it is a great wanderer, and decidedly more given to extended migrations than is any other species of its tribe. It breeds abundantly in the fur countries and sparingly or locally in the United States, just how far to the southward is not definitely known.

Megascops xantusi, sp. nov.

XANTUS'S SCREECH OWL.

Scops asio, var. *maccalli* Baird, Brewer, and Ridgway, Hist. N. Amer. Birds, III. 1874, 52, 53, part (descr. first full, but incomplete plumage from Cape St. Lucas; crit.).

Scops trichopsis? (not of Wagler) Ridgway, Proc. U. S. Nat. Mus., V. 1883, 533, footnote (Cape St. Lucas).

(?) *Scops* —— Belding, *Ibid.*, VI. 1883, 349 (Victoria Mts.; Agua Caliente; Miraflores). Ridgway, *Ibid.* (crit.).

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[1] Mr. Ridgway writes me that he cannot find this specimen, and that he does not "know what can have become of it."

Scops RIDGWAY, *Loc. cit.* (Cape St. Lucas; crit.).
Megascops asio trichopsis (not *Scops trichopsis* WAGLER) BRYANT, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 284 (Cape Region; ? Victoria Mts., etc.).

Specific Characters: — Most nearly like *M. vinaceus* Brewster,[1] but smaller, the general coloring paler and less reddish, the crown and outer surfaces of the wings lighter, the primaries with broad, well-defined light bars on *both* webs, the abdomen and flanks decidedly whiter, the under tail coverts nearly pure white and practically without mesial streaks, the feathering of the legs shorter and sparser.

♂ ad. (No. 47,301, collection of William Brewster, Santa Anita, Lower California, June 3, 1896; Loye Miller).[2] Upper parts drab, tinged with pinkish rusty on the back, inclining to ashy on the pileum and outer surfaces of the wings, to ashy white on the lores and sides of the crown, all the feathers except the primaries faintly vermiculated with reddish brown, those of the forehead, "ear tufts," back, rump, scapulars, and wing coverts with narrow shaft streaks of clove brown; primaries, secondaries, and tail-feathers barred with wood-brown, the bars on the tail narrow and distinct, excepting near the tips of the feathers, where they are broken and confused, those of the wings broad and distinct on both webs of all the primaries, but only faintly defined on the inner secondaries; outer scapulars, greater wing coverts, and outer primaries, with their exposed outer edges, hoary white; cheeks, throat, and breast pale ashy with the faintest possible suffusion of pinkish or rusty; abdomen, flanks, and crissum soiled white or ashy white; most of the feathers of the under parts with exceedingly fine, wavy, transverse lines of reddish brown, those of the throat, breast, and sides (but not of the under tail coverts nor of the center of the abdomen) with narrow, sharply-defined, mesial streaks of dark clove brown; tibiae tinged with fulvous and barred with reddish brown; under wing coverts pale fulvous heavily marked with dark brown; tarsi rusty white with a few reddish brown spots; toes naked nearly to their bases. Wing, 5.35; tail, 2.72; tarsus, 1.32; middle toe, .65; bill, length from nostril, .32; depth at nostril, .40; longest feathers of "ear tufts," .90.

Two young birds (No. 16,932 ♂ and No. 16,933 ♀, U. S. National Museum Collection, Cape St. Lucas; J. Xantus), fully grown but still in juvenal plumage, differ from the adult specimen just described in being much darker, browner, and more uniformly colored, in lacking all trace of mesial or shaft streaks on the feathers of the body, and in having the broad, light bars on the wing quills more rusty and nearly as pronounced and well defined on both webs of all the secondaries as on those of the primaries. The upper parts are faded reddish brown (not far from russet) with obscure, transverse lines of whitish on the pileum, back, and wing coverts; the cheeks, throat, and under parts generally are everywhere crossed by bands of reddish brown, which are much narrower than the brownish-white interspaces; the feathering of the legs is even scantier than in the mature bird.

On comparing both old and young with specimens in corresponding plumages of *bendirei*, *trichopsis*, and *cineraceus*, the only representatives of the *M. asio* group known to occur along the southwestern border of the United States, I have become convinced that the Lower California bird is not likely to have been derived from any of these races. It is, indeed, so very unlike all of them and so similar in general appearance to the Mexican form *vinaceus* that I regard it as most nearly related to, and probably a direct offshoot from, the latter. The two birds, *xantusi* and *vinaceus*, with still another Mexican form, *M. cooperi*, appear to constitute what may be termed a subsection of the *M. asio* group, for although differing from one another in size they have the same general pattern of color and marking. This pattern is, in certain respects, unlike that common to the various races of *M. asio*, the principal differences consisting in the exceedingly fine vermiculation and more or less pronounced pinkish tone of the plumage of all three of the Mexican birds just mentioned. I will further remark in this connection that the form *trichopsis* seems to me to be perfectly distinct, specifically, from *M. asio*. Indeed, I do not see how it can be otherwise regarded, for it differs very strikingly from *cineraceus*, the only other representative of *asio* found in southern Arizona, where, moreover, both *trichopsis* and *cineraceus* appear to breed together, or at least in close proximity.

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[1] Type locality: Durasno, Chihuahua, Mexico; see Auk, V. 1888, 88.

[2] This specimen was purchased from Mr. C. K. Worthen.

The sum as well as character of the differences which distinguish *M. xantusi* from the other members of the genus Megascops would not, in my estimation, warrant its recognition as a full species were it not for the obvious and practically complete isolation of its habitat from the regions inhabited by all the others, and especially from the habitat of its nearest ally, *M. vinaceus*. Were it at all closely related to the California form, *bendirei*, we might safely assume that it is likely to meet and intergrade with the latter in the central or northern parts of the Peninsula, but the two are so very unlike that the possibility of such intergradation is not worth considering.

Very little can be said at present regarding the distribution, and practically nothing concerning the habits, of this pretty little Screech Owl which I have named for the ornithologist by whom the first and hitherto only known specimens were obtained. Mr. Frazar did not meet with it, but it was, no doubt, the bird whose "tremulous notes" were heard at night by Mr. Belding at several of his camps in the Victoria Mountains as well as at Agua Caliente and Miraflores, and it may also have been the species with which Mr. Bryant had a similarly unsatisfactory experience "at the dry camp, Cardon Grande, and at El Rancho Viejo." According to the observer last named, "Mr. Anthony has seen a screech owl on several occasions between Valladares and the coast," but the bird of this region is most likely to be *M. a. bendirei*, which probably ranges southward into the northern portions of Lower California.

Bubo virginianus elachistus, subsp. nov.[1]

DWARF HORNED OWL.

Bubo virginianus (not *Strix virginiana* GMELIN) BAIRD, Cat. N. Amer. Birds, 1859, no. 48, part; Proc. Acad. Nat. Sci. Phila., 1859, 301, 302 (Cape St. Lucas). SHARPE, Cat. Birds Brit. Mus., II. 1875, 19–23, part.

[*Bubo virginianus*] var. *arcticus* COUES, Key N. Amer. Birds, 1872, 202, part.

Bubo virginianus, var. *arcticus* COUES, Check List, 1873, 63, no. 317 a, part. BAIRD, BREWER, and RIDGWAY, Hist. N. Amer. Birds, III. 1874, 64, part (Lower California).

Bubo virginianus subarcticus (not *Bubo subarcticus* HOY) RIDGWAY, Nom. N. Amer. Birds (Bull. U. S. Nat. Mus., no. 21), 1881, 36, no. 405 a, part; Proc. U. S. Nat. Mus., VI. 1883, 349 (crit.; Victoria Mts.). BELDING, *Ibid.*, V. 1883, 543 Cape Region); VI. 1883, 349 (Victoria Mts.). BRYANT, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 284 (Cape Region; Victoria Mts.).

Bubo virginianus arcticus COUES, Check List, 2d ed., 1882, 80, no. 463, part.

B.[*ubo*] *virginianus subarcticus* RIDGWAY, Man. N. Amer. Birds, 2d ed., 1896, 263, part.

Subspecific Characters: — Similar to *Bubo virginianus saturatus*, but very much smaller.

Measurements: —

			Wing	Tarsus	Length of bill from nostril
Male	*Type*, No. 17,866	Sierra de la Laguna, May 31, 1887, M. Abbott Frazar	12.96	2.45	.85
Male	No. 17,865	San José del Rancho, July 20, 1887, M. Abbott Frazar	13.20	2.50	.85
Male	No. 47,302	Santa Anita, July 17, 1896, Loye Miller	12 52	2.28	.80
		Average	12.89+	2.41	.83+
Female	No. 17,867	Sierra de la Laguna, April 29, 1877, M. Abbott Frazar	13.42	2.35	.89

This dwarf form of *B. virginianus*, the smallest, if I am not mistaken, which is at present known, at least from any part of North America, is represented in my collection by four adult birds, three of which are colored and marked nearly like average specimens of *saturatus*. The fourth appears much paler, but it is in excessively worn condition, and a number of new feathers sprouting among and beneath the old and faded ones indicate that the fresh plumage, when completed, would have been as dark as that of the other three skins. There is a specimen in the National Museum, however, obtained by Mr. Xantus in the Cape Region, which, although apparently neither worn nor faded, is nearly as light-colored as average examples of *B. v. pallescens*. Mr. Oberholser, who is at present engaged in a critical study of the entire *B. virginianus* group, tells me that he has noted similar color variations in most of the forms which he has examined, and that he regards them as representing different and probably permanent color phases comparable to, although less conspicuous than, those which are found in so many of the members of the genus Megascops.

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[1] In April of the present year I showed my Horned Owls from the Cape Region to Mr. Oberholser. He told me that he had decided to describe the form which they represent, but finding that I had already done this in manuscript and that my paper was likely to appear before his, he was kind enough to suggest that I use the above name, which he had selected and which is derived from the Greek ἐλάχιστος = least.

Mr. Frazar found this Owl nearly everywhere from the coast to the tops of the highest mountains, but not commonly except on the Sierra de la Laguna, where as many as three or four were often heard hooting at once. Mr. Belding had a similar experience, rarely meeting the bird in the low country, whereas it was "frequently heard and occasionally seen" at the higher elevations. Its preference for the mountains is doubtless due to the fact that they afford the only extensive forests of large trees which exist in this region, for *Bubo virginianus* is comparatively indifferent to considerations of mean temperature and equally at home in subtropical, temperate, or subarctic climates. This, however, can be said only of the *species*, as the adaptation of the individual to extremes — whether of heat or cold, moisture or dryness — must be usually very gradual, for in most cases it has been accompanied by modifications of color or physique sufficiently pronounced to distinguish birds which have become established in one region from those of another where the climatic conditions are widely different. The Horned Owls which inhabit the southern extremity of Lower California afford a good illustration of this fact, for, as has been already pointed out, they differ considerably from all the forms which occur in other parts of North America. I have seen no specimens from anywhere on the Peninsula north of La Paz, and hence have no means of judging just how far northward the present subspecies extends, but Mr. Bryant states that "on the peninsula opposite Magdalena Island, I found in a giant cactus a bulky nest of sticks upon which could be seen two young" Horned Owls, and "at Comondu an owl of this genus was several times seen at the opening of a small cave high up in the cliff," while at Ubi one was heard hooting on the night of May 9, 1889, and at Calmalli a feather was picked up in the trail. Mr. Anthony also met with Horned Owls "among the pines on San Pedro Martir at 2,500 to 10,000 feet elevation" (Bryant).

Speotyto cunicularia hypogaea (Bonap.).

Burrowing Owl.

Speotyto cunicularia hypogaea Belding, Proc. U. S. Nat. Mus., V. 1883, 543 (Cape Region). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 285 (Cape Region).

Mr. Belding and Mr. Frazar agree in considering the Burrowing Owl a rare bird in the Cape Region, where it is apparently confined to the low country near the coast. Mr. Frazar met with it on only two occasions; at La Paz, on April 4, when one which had been accidentally drowned in a water tank was brought to him by a boy, and at San José del Cabo, on October 26, when another was seen "in thick brush." The bird seems to be but little more numerously represented in the central and northern portions of the Peninsula, for Mr. Bryant mentions only one "seen by me on Cerros Island in January, 1885;" a female shot on March 1, 1889, on Santa Margarita Island; one or two observed by Mr. Brandegee on Magdalena Island; and a few found by Mr. Anthony at San Quintin. The latter observer has also recorded the occurrence of "a few in the more open valleys between the mines and the coast" at San Fernando,[1] as well as of others "seen in several of the valleys between Tia Juana and San Telmo."[2]

The range of the Burrowing Owl in western America extends from British Columbia to Mexico, and the bird is believed to breed wherever found.

Glaucidium hoskinsii (Brewst.).

Hoskins's Pygmy Owl.

Glaucidium gnoma Ridgway, Nom. N. Amer. Birds (Bull. U. S. Nat. Mus., no. 21), 1881, 37, no. 409, part. Coues, Check List, 2d ed., 1882, 83, no. 484, part. A. O. U., Check List, 1886, 204, 205, no. 379, part.

[*Glaucidium*] *passerinum*, var. *californicum* Coues, Key N. Amer. Birds, 1872, 206, part.

Glaucidium passerinum, var. *californicum* Coues, Check List, 1873, 67, no. 329, part.

Glaucidium gnoma hoskinsii Brewster, Auk, V. 1888, 136 (orig. descr.; type from Sierra de la Laguna). Bendire, Life Hist. N. Amer. Birds, pt. I. 1892, 408, 409 (Sierra de la Laguna; breeding habits and eggs unknown).

Glaucidium hoskinsii Brewster MS., A. O. U. Comm., Suppl. to Check List, 1889, 9; Check List, abridged ed., 1889, and 2d ed., 1895, no. 379.1. Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 285 (Sierra de la Laguna; Comondu). Ridgway, Man. N. Amer. Birds, 2d ed., 1896, 593, 594 (descr.; mts. S. Lower Calif.).

G.[*laucidium*] *gnoma* Coues, Key N. Amer. Birds, 4th ed., 1894, 514, part.

Glaucidium hoskinsi Allen, Auk, X. 1893, 142 (tropical type). Coues, Key N. Amer. Birds, 4th ed., 1894, 904 (descr.; Lower Calif.).

[*Glaucidium*] *hoskinsi* Sharpe, Hand-list, I. 1899, 298.

This little Owl was discovered by Mr. Frazar on the Sierra de la Laguna, where it frequents the largest pines and oaks on the top and sides of the mountain. It appears to be rather common, for several were heard calling almost every night in May and early June. "Their notes resemble the syllables *cow*, *cow*, *cow*, repeated a number of times." Only three specimens were secured. Of these one was followed after dark and shot while in the act of calling; another was started from some thick brush in the daytime; and the third, also shot by daylight, was sitting in a tree surrounded by a noisy and excited mob of little birds, chiefly Baird's Juncos. During Mr. Frazar's autumn visit to the Sierra only one of these Owls was heard, on the night of November 30. Probably they do not call freely at this season.

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[1] Auk, XII. 1895, 138.

[2] Zoe, IV. 1893, 235.

Hoskins's Owl is apparently not confined to the Cape Region, for Mr. Bryant reports that he "shot a male at Comondu, March 22, 1889."

Micropallas whitneyi (Cooper).

Elf Owl.

Micrathene whitneyi Belding, Proc. U. S. Nat. Mus., V. 1883, 549 (Miraflores); VI 1883, 349 (Victoria Mts.)

Micropallas whitneyi Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 285 (Victoria Mts.; Miraflores). Bendire, Life Hist. N. Amer. Birds, pt. I. 1892 411 (Miraflores).

Two specimens of this Owl, collected by Mr. Belding, have been sent me for examination by Mr. Ridgway. They are labeled respectively: 87,605 "Nat. Mus., Miraflores, Lower Cal., May 5, 1882, ♀, L. Belding," and 87,263 "Nat. Mus., Miraflores Village, May 8, 1882, L. Belding coll., ♂ I believe—not certain." Both are considerably deeper colored, especially above, than any of my Arizona examples, the former having the upper parts decided ashy brown instead of faded grayish brown, as in the latter. No. 87,605 lacks nearly all trace of the usual abundant and conspicuous rusty markings on the face and under parts, while the rusty spots on the crown, back, and wings are comparatively few and faint. No. 87,263 has the rusty of normal extent, but of a somewhat richer tint than usual. Neither specimen shows any apparent approach to the deep rusty colored and evidently quite distinct *M. graysoni* of Socorro Island.

Mr. Belding asserts that he found the Elf Owl "common, if not abundant" at Miraflores in 1882, and that he also met with it in "the mountains" in 1883, but it "appeared to be less common here than in the cactus regions" at lower levels. Mr. Bryant supplements this by stating that Mr. Belding collected four examples at Miraflores in April, 1882, but did not succeed in obtaining any in the mountains. This is of some importance, in view of the fact that Mr. Frazar failed not only to obtain specimens, but even to see or hear the bird, although during the nine months which he spent in Lower California, he went over most of the ground covered by Mr. Belding. He made no collections at Miraflores, however.

The Elf Owl has not been found as yet in the central or northern portions of the Peninsula, but it occurs in southern California and Arizona as well as in northwestern Mexico.

Crotophaga sulcirostris SWAINS.

GROOVE-BILLED ANI.

Crotophaga sulcirostris BELDING, Proc. U. S. Nat. Mus., V. 1883, 546 (San José del Cabo; breeding; descr. nest). BRYANT, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 285 (San José del Cabo); Zoe, II. 1891, 191, 192 (San José del Cabo). BENDIRE, Life Hist. N. Amer Birds, pt. II. 1895, 13, pl. 1, fig. 7 (descr. egg from near San José del Cabo, "an unscratched specimen").

Mr. Frazar met with the Groove-billed Ani only at San José del Cabo, where a flock of about thirty frequented some thick brush about pools of water near the mouth of the river. On August 28 a nest, empty, but apparently just finished, was found, and a perfect egg was taken from a female bird shot near at hand, and probably the owner of this nest. On September 3 another nest, containing three fresh eggs, was taken. These dates indicate either a very extended breeding season or great irregularity of breeding in different years, for at the same place in 1882 Mr. Belding found a nest which contained eight eggs on April 29. The latter observer also met with Groove-billed Anis "among tules at Santiago and at San Pedro on the western coast near Todos Santos," according to Mr. Bryant.

The nest found by Mr. Belding "was fastened to upright reeds, and was composed of coarse weed stalks and mesquit twigs, lined with green leaves." That taken by Mr. Frazar was in a willow about twenty feet above the ground. It is a flat, loose, but withal rather neat structure, formed outwardly of dead twigs and very substantially lined with cottonwood and willow leaves, which look as if they must have been dry when gathered. Mr. Frazar is very sure that such was the case, although he has no distinct recollection of their condition at the time the nest was found. This nest measures about six inches across the top, and the cavity is nearly an inch in depth. The eggs measure respectively: 1.22 × .95, 1.24 × .98 and 1.25 × .97. They are verditer blue, but this color becomes visible only on scraping off the whitish, calcareous substance with which their shells are uniformly and rather thickly covered. One side of each egg is stained with light reddish brown, evidently from contact with something in the nest. The egg already referred to as taken from the oviduct of a bird shot on August 23 is without any trace of this stain, but it has a calcareous coating like the others. It measures 1.25 × .98.

The Groove-billed Ani also inhabits the valley of the Lower Rio Grande in Texas as well as Mexico, Central America and northern South America. As it is not known to occur in central or northern Lower California, it seems probable that the colonies which have become established in the Cape Region were originated by birds which came from western Mexico.

Geococcyx californianus (Less.).

ROAD-RUNNER.

Saurothera californiana Botta, Nouv. Ann. Mus., IV. 1835, 123, pl. 9 (Cape St. Lucas).

Geococcyx californianus Baird, Proc. Acad. Nat. Sci. Phila., 1859, 301, 303 (Cape St. Lucas). Baird, Brewer, and Ridgway, Hist. N. Amer. Birds, II. 1874, 473 (Xantus's specimens from Cape St. Lucas "smaller than those of Upper California"). Belding, Proc. U. S. Nat. Mus., V. 1883, 543 (Cape Region). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 285 (Cape Region).

Road-runner Bryant, Zoe, II. 1891, 192 (San José del Cabo).

Mr. Belding and Mr. Frazar are somewhat at odds in their views regarding this species, the former noting it as "common" without qualification as to certain localities, the latter as "a rare bird everywhere excepting at San José del Cabo, where it was fairly common, but confined almost exclusively to the gardens and green thickets along the river."

P. E. Botta stated as early as 1835 that the range of the Road-runner extends from Cape St. Lucas to San Francisco. Mr. Bryant, however, reports seeing "but one individual while crossing the peninsula from the Ocean to the Gulf in the latitude of Comondu" despite "the abundance of lizards and other suitable food," and adds that "they were rarely seen along the route from Comondu to San Quintin," although a little further northward "Mr. Anthony has found them from the coast to well into the pines on San Pedro Martir at an altitude of 7,000 feet" (Bryant), and "quite common about the mines, and much more so near the water holes near the mission" at San Fernando.[1]

The Road-runner occurs from California to Mexico, and is strictly resident wherever found.

Coccyzus americanus occidentalis Ridgw.

CALIFORNIA CUCKOO.

This Cuckoo, which is now reported from the Cape Region for the first time, was found by Mr. Frazar only at San José del Rancho, where it "first appeared on July 5, and soon became rather common, but did not begin nesting until the latter part of the month.' It probably occurs on the Sierra de la Laguna, also, for the people living there described it to Mr. Frazar, asserting that "it comes only in the time of the waters," *i. e.*, the rainy season, which begins in July. This was confirmed by a man at San José del Rancho, who spends much time on the Sierra hunting deer, and who, seeing a Cuckoo in Mr. Frazar's possession, remarked that he had often met with the bird on

[1] Anthony, Auk, XII. 1895, 138.

the mountain in midsummer. The lateness of its arrival in this region is remarkable, in view of the fact that its reaches California in May or early June.

Mr. Bryant reports that a Cuckoo which was probably *occidentalis* has been seen in August by Mr. Anthony at Ensenada, near the northern boundary of Lower California.

The California Cuckoo is found from Oregon to Costa Rica, on or near the Pacific coast, and, everywhere north of Mexico, at least, is migratory, going further south to pass the winter.

Ceryle alcyon (Linn.).

Belted Kingfisher.

Ceryle alcyon Belding, Proc. U. S. Nat. Mus., V. 1883, 543 (Cape Region). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 286 (Cape Region).

Belted Kingfishers from Lower California, as well as those from the western United States generally, average larger than eastern birds. They also have stouter bills. As these differences are neither constant nor accompanied by any obvious geographical modifications of color or markings, it seems to me quite enough merely to mention them in passing.

Mr. Frazar found the Kingfisher rare at La Paz, but rather common about San José del Cabo. Mr. Belding gives it as common, but mentions no special localities. It apparently occurs only in autumn, winter and early spring. At these seasons it has been seen at various localities in the upper part of the Peninsula by Mr. Bryant and Mr. Anthony.

The Belted Kingfisher ranges from Alaska to Panama, but is not known to breed south of the southern boundary of the United States. Throughout California and northward to British Columbia it is found during both summer and winter, wherever there are clear streams that contain an abundance of fish.

Dryobates lucasanus (Xantus).

St. Lucas Woodpecker.

Picus lucasanus Xantus, Proc. Acad. Nat. Sci. Phila., 1859, 298 (orig. descr.; type from Cape St. Lucas). Baird, *Ibid.*, 301 (Cape St. Lucas), 302 (crit.; Cape St. Lucas). Cassin, *Ibid.*, 1863, 195, 196 (descr.; Lower Calif.). Malherbe, Mon. Picidae, I. 1861, 166 (descr.; Cape St. Lucas). Sclater, Cat. Amer. Birds, 1862, 333 (Cape St. Lucas). Gray, List Birds Brit. Mus. 1868, 50 (Lower Calif.). Elliot, Illustr. New and Unfig. N. Amer. Birds, I. 1869, introd. (figures head and leg; probably equals *Picus scalaris*). Coues, Key N. Amer. Birds, 1872, 193 (crit.; Cape St. Lucas).

D.[*ictyopipo*] *lucasana* Cab. & Heine, Mus. Hein., pt. IV. sect. 2, 1863, 75, 76 (descr.; Cape St. Lucas).

[*Picus*] *lucasanus* Gray, Hand-list, II. 1870, 186, no. 8,612.

Picus scalaris, var. *lucasanus* Cooper, Orn. Cal., 1870, 381, 382 (descr.; crit.; figures head and bill; Cape St. Lucas). Coues, Check List, 1873, 59, no. 297 b. Baird, Brewer, and Ridgway, Hist. N. Amer. Birds, II. 1874, 519, 520 (descr.; crit.; Cape St. Lucas). Jasper, Birds N. Amer., 1878, 158, pl. 105, fig. 26 (Cape St. Lucas).

Picus scalaris lucasanus Ridgway, Nom. N. Amer. Birds (Bull. U. S. Nat. Mus., no. 21), 1881, 34, 65, 75, no. 363 a; Proc. U. S. Nat. Mus., VI. 1883, 158, footnote (crit.; S. Lower Calif.). Coues, Check List, 2d ed., 1882, 77, no. 436. Belding, Proc. U. S. Nat. Mus., V. 1883, 543 (Cape Region); VI. 1883, 345 (Cape Region), 349 (Victoria Mts.).

P.[*icus*] *scalaris lucasanus* Belding, *Loc. cit.*, 344 (Lower Calif.).

Dryobates scalaris lucasanus Ridgway, Proc. U. S. Nat. Mus., VIII. 1885, 355. A. O. U., Check List, 1886, 212, no. 396 a. Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 286 (Cape Region; Cape St. Lucas; Victoria Mts.; Santa Margarita Island, etc.). Townsend, Proc. U. S. Nat. Mus., XIII. 1890, 137 (Cape St. Lucas). Allen, Auk, X. 1893, 142 (tropical type). Anthony, Zoe, IV. 1893, 236 (San Pedro Martir); Auk, XII. 1895, 138 (San Fernando; San Telmo). Bendire, Life Hist. N. Amer. Birds, pt. II. 1895, 65 (Cape Region, etc.). Miller, Auk, XI. 1894, 178 (San Diego co., Calif.).

Dendrocopus lucasanus Hargitt, Cat. Birds Brit. Mus., XVIII. 1890, 250 (descr.; La Paz; Cape St. Lucas; subsp. of *Dendrocopus scalaris*).

Dryobates [*scalaris lucasanus*] Bryant, Zoe, II. 1891, 191 (San José del Cabo).

P.[*icus*] *s.* [*calaris*] *lucasanus* Coues, Key N. Amer. Birds, 4th ed., 1894, 482 (descr.; Cape St. Lucas).

D.[*ryobates*] *scalaris lucasanus* Ridgway, Man. N. Amer. Birds, 2d ed., 1896, 285 (descr.; s. portion of Lower Calif.).

[*Picus scalaris*] var. *lucasana* Dubois, Synop. Avium, fasc. I. 1899, 71 (Basse-Californie).

[*Dendrocopus*] *lucasanus* Sharpe, Hand-list, II. 1900, 215.

All the characters which have been proposed for this Woodpecker are shown by the large series before me to be subject to much variation, but this, as in the case of *Melanerpes angustifrons*, is confined within limits which do not overlap, if, indeed, they quite reach those of the bird's nearest allies. The restriction of the black on the outer tail feathers is perhaps its best distinguishing feature, although this is not at all uniform, for many of my specimens have three complete dark bars crossing both webs of the outer tail feathers, while in one a fourth bar is only broken by a small space near the middle of the feather. The width of the dark bars on the back is also variable, although these bars are usually wider than in any of the allied forms. The feet average larger than those of *bairdi*, but they are by no means *always* larger. A difference which I do not find mentioned in descriptions, but which is shown by my series to be quite as constant as most of the characters that have been proposed, is that the white spots on the top of the head are much larger and more numerous than in *bairdi*, while the red is less vivid and more nearly restricted to the crown and occiput. In one specimen (No. 17,231, La Paz, March 26,

1887) this red is confined to the occiput and a narrow border on the side of the crown posterior to the eye, the remainder of the head above being plain black spotted with white.

Spring birds of both sexes are paler beneath than autumnal specimens, the latter having a decidedly browner cast. None of the females in my large series show any red on the head, but more than fifty per cent of them have the feathers of the forehead streaked with dull white. In one bird (No. 17,205, Santiago, Nov. 24, 1887) this white streaking extends over the entire crown, only the occiput being unmarked. Many specimens of both sexes have the white markings of the wings and tail tinged with brown, evidently a stain. In a few specimens this brownish is also conspicuous on the breast and throat.

Mr. Frazar considers this Woodpecker "rather common and generally distributed in the Cape Region, except on the mountains, where it was not met with." He found it most numerous about La Paz, but did not see it anywhere to the northward of that place during his trip along the Gulf coast. Mr. Belding includes it in his list of "Birds of the Mountains," but says that it was "rarely seen." On the Pacific coast of the Peninsula he traced it to a point thirty miles north of Todos Santos, which, however, by no means marks the limit of its distribution in this direction, for Mr. Bryant found it on Santa Margarita Island, and afterwards collected specimens as far north as latitude 28°. It has since been reported by Mr. Anthony[1] as "abundant about the cardoon and cirio trees" at San Fernando (lat. 29° 30′), where "young were seen in families of four or five" in June, and where the bird was "not uncommon along the coast and lower foothills as far as San Telmo at least, living in the thickets of pitahaya cactus (*Cereus gummosus*), and nesting in the dry flower stalks of the mescal agave which grows with the cactus. San Fernando and San Telmo skins are indistinguishable from those from Cape St. Lucas."

Although the St. Lucas Woodpecker is practically confined to the Peninsula it has been recorded from the northern part of San Diego county, California, by Mr. G. S. Miller, jr.[2]

Sphyrapicus varius nuchalis Baird.

Red-naped Sapsucker.

Sphyrapicus varius nuchalis Belding, Proc. U. S. Nat. Mus., VI. 1883, 349 (Laguna).
Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 286 (La Laguna).

A Red-naped Sapsucker "obtained at Laguna," on February 1, 1883, by Mr. Belding, is the only specimen known to have occurred in Lower California. The bird is probably of rare and irregular occurrence here (if, indeed, anything more than a mere waif) for its true home is the Rocky Mountain region and south into northern Mexico. A few specimens have been taken in southern

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[1] Auk, XII. 1895, 138.

[2] Auk, XI. 1894, 178.

California, however, some of them among the foot-hills not far from the coast. The form characteristic of California (*S. ruber*) is found in the northern part of Lower California.

Melanerpes angustifrons (Baird).

Narrow-fronted Woodpecker.

Melanerpes formicivorus Cassin, Proc. Acad. Nat. Sci. Phila., 1863, 328 part (crit.; Lower Calif.).

Melanerpes formicivorus, var. *angustifrons* Baird, in Cooper, Orn. Cal., 1870, 405, 406 (orig. descr.; type from Cape St. Lucas; figures heads of male and female). Coues, Check List, 1873, 63, no. 310 a. Baird, Brewer, and Ridgway, Hist. N. Amer. Birds, II. 1874, 573, pl. 53, figs. 3, 4 (descr.; crit.; Cape St. Lucas). Jasper, Birds N. Amer., 1878, 178, pl. 117, fig. 13 (Cape St. Lucas).

[*Melanerpes formicivorus*] var. *angustifrons* Coues, Key N. Amer. Birds, 1872, 197 (descr.; Cape St. Lucas). Dubois, Synop. Avium, fasc. I. 1899, 68 (Basse-Californie).

Melanerpes angustifrons Baird, Brewer, and Ridgway, Hist. N. Amer. Birds, II. 1874, pl. 53, figs. 3, 4. Hargitt, Cat. Birds Brit. Mus., XVIII. 1890, 153, 154 (descr.; Sierra de la Laguna; Triunfo).

Melanerpes formicivorus angustifrons Ridgway, Nom. N. Amer. Birds (Bull. U. S. Nat. Mus., no. 21), 1881, 35, 65, 75, no. 377 a; Proc. U. S. Nat. Mus., VI. 1883, 158, footnote (crit.; S. Lower Calif.). Coues, Check List, 2d ed., 1882, 79, no. 455. Belding, Proc. U. S. Nat. Mus., V. 1883, 549 (Miraflores); VI. 1883, 349 (Victoria Mts.). A. O. U., Check List, 1886, 216, no. 407 a. Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 287 (Miraflores; Victoria Mts.). Bendire, Life Hist. N. Amer. Birds, pt. II. 1895, 117 (Cape Region; gives Wm. Brewster's description of eggs from Sierra de la Laguna).

M.[elanerpes] f.[ormicivorus] angustifrons Bryant, Zoe, II. 1891, 198 (Victoria Mts.). Coues, Key N. Amer. Birds, 4th ed., 1894, 490 (descr.; Lower Calif.)

M.[elanerpes] formicivorus angustifrons Ridgway, Man. N. Amer. Birds, 2d ed., 1896, 291 (descr.; s. portion of Lower Calif.).

[*Melanerpes*] *angustifrons* Sharpe, Hand-list, II. 1900, 209.

The characters originally given to this species, although in my opinion sufficiently pronounced and constant to separate it *specifically* from its nearest allies, are subject to considerable variation within certain limits. Thus both the white frontal band and the black band which, in the female, borders it posteriorly, vary greatly in width. The white in a few of my specimens extends back as far as the anterior corner of the eye and the black is nearly twice as wide (longitudinally) in some birds as in others, but the combined width of the white and black does not appear ever to exceed the width of the red patch on the crown and occiput, although in at least one of my examples it fully equals it. None of my birds have the forehead "gamboge," but it is tinged with citron yellow in many specimens; in the majority it is soiled white. In one bird, a female, it is spotted with black. Another female has the black band on the crown plentifully sprinkled with red of the same tint as that of the occiput. The red of the occiput varies only slightly in shade with different birds. The amount of white streaking on the breast is also very uniform, although a single specimen (female, No. 17,332, Sierra de la Laguna, June 3, 1887), which, in other respects, is a typical *angustifrons*, has the black of the breast unstreaked over quite as broad a space as in average specimens of *bairdi*. About fifty per cent of my specimens of both sexes show more or less crimson red on the middle of the breast, this sometimes forming a rather large and distinct patch. A small number, perhaps five per cent, also of both sexes, have the plumage curiously variegated with light brown, varying from cinnamon to Vandyke brown. This is usually confined to the ends of the wing quills and tail feathers, but in a few specimens it extends over the whole dark portions of these feathers. One bird (female, No. 17,257, Triunfo, December 20, 1887), has not only much of the wings and tail, but also the wing coverts, shoulders, foreback and sides of the breast conspicuously washed with this light cinnamon brown. In another (male, No. 17,300, Sierra de la Laguna, June 3, 1887), the greater coverts of the left wing and some of the scapulars over the right wing are distinctly brown. I am quite at a loss to explain this peculiar coloring. It does not seem to result from a faded condition of the plumage, for some of the birds most affected are autumn specimens which had just moulted; nor can it be a stain, for many of the feathers are clear, light brown to their bases, showing no underlying tones of black, as would be the case had they been affected by any extraneous dye. Some of the feathers again have the centers glossy black bordered on all sides by brown. Occasional specimens of other Woodpeckers in my collection, notably *Dryobates arizonae* and *D. v. hyloscopus*, exhibit similar light brown markings.

This Woodpecker, which seems to be strictly confined to the Cape Region proper, is exceedingly abundant throughout the pine forests on the higher mountains south of La Paz and common at many places in the oaks at the bases of the mountains and among their foot-hills, ranging downward, according to Mr. Belding, to an elevation of about 700 feet. Mr. Frazar found it most numerous on the Sierra de la Laguna, during the last week of April and the first week of May. After that its numbers decreased perceptibly. It began breeding on this mountain the first week in June, but the breeding season was not at its height until the middle of that month.

Four fresh eggs, constituting a set, taken by Mr. Frazar on June 3, are white with a rather dull gloss — about as in average eggs of *Sphyrapicus varius*. They vary in shape from blunt ovate to broad elliptical oval and measure respectively: .95 × .75, .94 × .74, .89 × .77 and .89 × .76. This set is unaccompanied by any notes regarding the position or character of the nesting hole or of the behavior of the birds.

Only one specimen was seen at Triunfo during the last two weeks of June, but the bird was common and presumably breeding at Pierce's Ranch in July. At the latter place it fairly swarmed in December, the resident colony being probably augmented by large numbers of winter visitors from La Laguna, where Mr. Frazar found only a few birds lingering in late November and early December. Along the road between San José del Cabo and Miraflores it was seen in considerable numbers on November 15, and three were observed in some evergreen oaks at Santiago on November 23.

This Woodpecker, like its near allies *M. formicivorus* and *M. f. bairdi*, has the habit of storing acorns in holes which it pecks for their reception in the trunks of trees. On the Sierra de la Laguna Mr. Frazar found "many dead pines literally stuffed full of acorns."

M. f. bairdi, the form found throughout California, passes the southern boundary of that State and ranges as far south on the Peninsula as San Pedro Martir, where it is not very numerously represented but "probably resident."[1]

Melanerpes uropygialis (Baird).

Gila Woodpecker.

Centurus uropygialis Baird, Proc. Acad. Nat. Sci. Phila., 1859, 301, 302 (Cape St. Lucas). Belding, Proc. U. S. Nat. Mus., V. 1883, 543 (Cape Region); VI. 1883, 345 (Cape Region).

Melanerpes uropygialis Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 287 (Cape Region). Townsend, Proc. U. S. Nat. Mus., XIII. 1890, 137 (Cape St. Lucas; La Paz). Bendire, Life Hist. N. Amer. Birds, pt. II. 1895, 127 (vicinity of Cape St. Lucas).

My numerous Lower California specimens of this Woodpecker do not appear to differ from those which I have received from Arizona and northern Mexico.

Individual variations: — *Males.* The red of the crown varies from deep crimson to orange chrome, but its distribution is very uniform. The width of the dark bars on the back, rump, wings, etc., is highly variable; all my specimens have the rump and upper tail coverts distinctly barred. The color of the head, neck, and under parts varies from hair brown to buffy drab, the yellow of the belly from pale maize yellow to deep cadmium orange. Usually the yellow forms a broad, conspicuous patch, but in a few specimens it is faint and restricted. Several of the spring specimens are more or less stained with umber brown on the wings, tail, and under parts.

Females. In respect to the yellow of the belly, the brown of the head and under parts, the width of the dark barring, and the staining of the wings, tail, and breast, the females vary much as do the males. Most of them have the forehead lighter than the rest of the head and in a few it is pure light buff. One bird has the auriculars, *on one side of the head only,* decidedly buffy in contrast with the color of the rest of the head. Two birds (No. 17,355, Santiago, November 25, and No. 11,404, Triunfo, December 12, 1887), both in full autumn plumage, show traces of red on the crown, one having a single crimson-tipped feather; the other, two feathers crimson nearly to their bases.

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[1] Anthony, Zoe, IV. 1893, 236.

Seasonal variations: — Spring, autumn, and winter specimens are essentially similar to one another, but the birds taken in October and early November have the general coloring clearer, and that of the head and under parts a trifle ashier, than in those collected at other seasons.

In the Cape Region the Gila Woodpecker has apparently much the same distribution as *Dryobates lucasanus.* Neither Mr. Belding nor Mr. Frazar found it in the higher mountains, but both note its abundance throughout the low country, and Mr. Frazar obtained many specimens at Triunfo which is within the lower edge of the oak belt. Mr. Belding traced it to about thirty miles north of Todos Santos on the Pacific coast, but it extends still farther up the Peninsula, for Mr. Bryant "found a few on Santa Margarita Island, and met with them generally along the overland route" — just how far to the northward he neglects to state, however. Mr. Anthony says that "the range of this species along the Pacific slope [of the Peninsula] is exactly coëxtensive with that of *Cereus pringlei*, becoming common with that cactus a short distance below Rosario and seldom if ever being seen at any distance from the shelter of its mighty branches." [1]

The Gila Woodpecker is not, of course, confined to Lower California. Elsewhere it occurs more or less numerously in southeastern California, southern Arizona and western Mexico. It is apparently resident wherever found.

Colaptes chrysoides (Malh.).

Gilded Flicker.

Colaptes chrysoides Baird, Proc. Acad. Nat. Sci. Phila., 1859, 301 (Cape St. Lucas), 302, 303 (crit.; descr. male and female; Cape St. Lucas). Baird, Brewer, and Ridgway, Hist. N. Amer. Birds, II. 1874, 583, 584, pl. 54, fig. 2 (descr.; crit.; breeding at Cape St. Lucas, May 19). Belding, Proc. U. S. Nat. Mus., V. 1883, 543 (Cape Region); VI. 1883, 345 (Cape Region), 349 (Victoria Mts.). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 287 (Cape Region). Bendire, Life Hist. N. Amer. Birds, pt. II. 1895, 139 (vicinity of Cape St. Lucas). Salvin and Godman, Biol. Centr.-Amer., Aves, II. 1895, 405 (breeding at Cape St. Lucas; descr. male from La Paz).

My Lower California specimens appear to be in every way identical with birds from Arizona and northern Sonora, Mexico. A pair from Alamos, southern Sonora, are much darker above, with the ashy of the throat and breast deeper and duller, and the under parts browner. If additional material from Mexico should show that these color peculiarities are constant they would be quite sufficient to warrant the separation of the birds which inhabit the region about Alamos.

Individual variations: — *Both sexes.* The rump and upper tail coverts are sometimes distinctly (but always finely) barred with black, sometimes immaculate white; the under wing coverts, usually profusely mottled and barred with blackish, are sometimes nearly plain; while the outer webs of the outer pair of tail feathers, as a rule notched distinctly with yellow, are occasionally plain black. The black markings on the under parts vary considerably in number and size, some specimens being profusely and heavily, others sparsely and finely, spotted. The barring of the upper parts is similarly variable, a few birds having the dark bars nearly obsolete on the back, although they are usually broad and distinct. None of my specimens show any red on the occiput or tinge of reddish in the yellow of the wings and tail; nor have any of the males black mixed with the red of the moustache. The ends of the wings and tail, as well as most of the under parts, are sometimes stained with umber, as in several other species of Woodpeckers from this region.

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[1] Auk, XII. 1895, 138, 139.

Seasonal variations: — Specimens in fresh autumn plumage have the general coloring a trifle clearer than do spring birds. I am unable to detect any other differences which can be associated with season.

Mr. Belding and Mr. Frazar agree as to the rarity of the Gilded Flicker on the higher mountains, where only a few individuals were seen by the former, and but two (both females, taken on the Sierra de la Laguna, April 29) obtained by the latter. The bird's true home is evidently at the bases of the mountains, and among their foot-hills extending thence to the shores of the Pacific on the south and west, to those of the Gulf on the east. Throughout this region it is a common species, although not so numerously represented as *Melanerpes uropygialis.* On the arid plains near the coast it breeds in the stems of the giant cactus. Mr. Bryant found it "rare on Santa Margarita Island," but it was "generally encountered along the overland route." Mr. Anthony has said that its "northwestern range" on the Peninsula "is almost, if not quite, the same" as that of *M. uropygialis*,[1] but soon after making this statement he found that the birds which occur in northern Lower California differ from those of the Cape Region "in darker upper parts and slightly smaller size." He has accordingly proposed to recognize the former as representing a distinct subspecies under the name *Colaptes chrysoides brunnescens.*[2] This form is said to be confined to northern Lower California, while typical *chrysoides* occurs not only in the central and southern portions of the Peninsula, but in Arizona and northwestern Mexico, also.

Phalaenoptilus nuttallii nitidus BREWST.

FROSTED POOR-WILL.

Phalaenoptilus nuttalli (not *Caprimulgus nuttallii* AUDUBON) BELDING, Proc. U. S. Nat. Mus., VI. 1883, 349 (Victoria Mts.).

I have only a pair of these Poor-wills from the Cape Region, both taken on the Sierra de la Laguna, the male on June 2, the female on June 6. They

[1] Auk, XII. 1895, 139.

[2] Auk, *Loc. cit.*, 347.

agree in all essential respects with *P. n. nitidus*, although the coloring of their upper parts is a trifle darker, and the terminal white tail band a little wider, than in my types of that subspecies. The Lower California male has the abdomen and flanks wholly without trace of dark bars.

P. n. nitidus seems to be a perfectly good subspecies, although its distribution is somewhat irregular and difficult to understand. It has been found in Texas, Kansas, and portions of Arizona, and it probably occurs in northwestern Mexico, also, although the bird of the Sierra Madre region is true *nuttallii*.

Mr. Belding was doubtless right in suspecting that he heard the notes of a Phalaenoptilus in the mountains of the Cape Region, for Mr. Frazar found the Frosted Poor-will very common on the Sierra de la Laguna in May and June. It was also noted in July at both Pierce's Ranch and Triunfo, but not commonly at either place. A single bird, probably a migrant on its way south, was heard at San José del Cabo on the evening of September 2.

Mr. Frazar states that on the mountains these Poor-wills did not begin singing until about the middle of May. "Their note is a *pow-wè-hoo*, the first syllable given long, the accent on the second, and the last little more than a retraction of the breath. They were almost invariably in large oaks and very seldom on the ground. A female shot June 6 was undoubtedly mated and would have laid soon."

Mr. Bryant records[1] *P. n. californicus* from Tia Juana, San Pedro Martir, and Pozo Grande. At the latter place a male was taken on March 19, 1889. Poor-wills were also "heard every evening on the steep hillsides at Comondu, and at various other localities," but the specimen just mentioned seems to be the only one actually examined by Mr. Bryant.

Mr. Anthony asserts that of three Poor-wills which he obtained in the northern part of the Peninsula in 1894 "two are rather intermediate between *californicus* and *nitidus*, although one was collected as far north as Burro Cañon, north of Ensenada. The third, No. 5,266, collected at San Fernando May 4, if not true *nitidus*, is not far from that form."[2]

Chordeiles acutipennis texensis (Lawr.).

Texan Nighthawk.

Chordeiles texensis Baird, Proc. Acad. Nat. Sci. Phila., 1859, 301, 303 (Cape St. Lucas). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 288 (Cape Region).

Chordeiles acutipennis, var. *texensis* Baird, Brewer, and Ridgway, Hist. N. Amer. Birds, II. 1874, 407 (abundant at Cape St. Lucas; breeding at Cape St. Lucas in May).

Chordeiles acutipennis texensis Belding, Proc. U. S. Nat. Mus., V. 1883, 543 (La Paz; San José).

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[1] Proc. Calif. Acad. Sci., 2d ser., II. 1889, 287, 288.

[2] Auk, XII. 1895, 139.

Numerous examples of this species in my collection from Lower California, Arizona, and western Mexico, show no appreciable geographical variations in respect to either size or color, but they average a trifle smaller and, as a rule, are somewhat lighter colored than a number of Texas specimens in the collection of the late Mr. Sennett.

Mr. Frazar saw the first Texan Nighthawk at Triunfo on the evening of April 15. It was next met with on the Sierra de la Laguna, where one or two were observed the last week in May. At Triunfo the birds were abundant during the last three weeks of June, appearing regularly every evening near the ranch, and skimming back and forth close over a large wood pile, which evidently harbored insects on which they were feeding. After a succession of heavy showers which occurred at this place early in July they suddenly and wholly disappeared. At San José del Cabo a few were seen at intervals through the autumn up to November 11, and several were observed near Santiago on December 3. Mr. Belding found the species "abundant at San José after April 23," but he says that it was "rarely seen at La Paz." As the latter statement presumably refers to some date or dates between December 15, 1881, and March 21, 1882, it seems fair to assume that the December instance noted by Mr. Frazar was not exceptional, and that at least a few birds regularly winter in the Cape Region. Mr. Frazar obtained a set of two eggs, slightly incubated, at Pierce's Ranch, on July 20.

The Texan Nighthawk seems to be generally distributed throughout the central and northern portions of the Peninsula, although, judging by Mr. Bryant's experience, it is nowhere very common to the northward of La Paz. Its extralimital range includes the lower border of the United States from southern California to eastern Texas, southward to Central America.

Chaetura vauxii (Towns.).

Vaux's Swift.

At San José del Cabo on September 24, and again on November 2, Mr. Frazar saw "a small black Swift" which he thought belonged to this species, and which, indeed, could not well have been anything else. On each occasion only a single bird was observed, but the one seen in September was accompanied by a number of Barn and Eave Swallows. *Chaetura vauxii* was of course to be expected in this region, at least as a migrant, but it has not been reported up to this time, although it was observed by Mr. Belding in May, 1885, between San Rafael and San Pedro Martir, in the northern portion of the Peninsula (Bryant).

Vaux's Swift is found on the Pacific slope from British Columbia south into Mexico. It is not known to breed south of San Francisco.

Aëronautes melanoleucus (Baird).

White-throated Swift.

Cypselus saxatilis Belding, Proc. U. S. Nat. Mus., V. 1883, 547 (San José del Cabo; San José).

Micropus melanoleucus Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 288 (San José del Cabo).

Two specimens, both males, taken on May 19 on the Sierra de la Laguna, are slightly smaller than the average of my Colorado examples, but are otherwise similar to the latter.

On the Sierra de la Laguna, during May and the first week in June, Mr. Frazar saw these Swifts almost daily, but never in very great numbers. They were usually observed flying along the sides of the mountain, and only once over its summit. The sexual organs of two males shot on May 19 were at the maximum stage of development, but Mr. Frazar obtained no other evidence that the species breeds in these mountains, nor did he find it elsewhere in Lower California. Mr. Belding, however, noted it at San José del Cabo on April 29, 1882.

The range of the White-throated Swift extends from California to Central America. It breeds at many places in the mountains of California as far south as San Bernardino.

Calypte costae (Bourc.).

Costa's Hummingbird.

Calypte costae Belding, Proc. U. S. Nat. Mus., V. 1883, 542 (Cape Region; San José; Cape St. Lucas; Miraflores), 547 (breeding at La Paz); VI. 1883, 348 (Victoria Mts.). Ridgway, *Ibid.*, V. 1883, 542 (descr. nests and eggs); Rep. U. S. Nat. Mus., 1889–1890, 1891, 337–339, pl. 39 (Cape district of Lower Calif.; figures female and nest from La Paz).

Trochilus costae Bryant, Zoe, II. 1891, 191 (San José del Cabo).

Lower California specimens do not appear to be in any way peculiar.

Individual variations: — Adult males. The amount of green on the back, sides, and abdomen is somewhat variable, and the length of the bill exceedingly so. Most of my specimens have the purplish of the forehead obscured by what appears to be a thin coating of pollen. In one taken at La Paz on February 24, 1887, the forehead and throat are covered with pin feathers.

Immature males. A male killed at La Paz on February 23, 1887, differs from the adult female only in having the plumage of the top and sides of the head browner and interspersed with a few (three or four) purple feathers. It is evidently a bird of the preceding year.

Adult females. In some specimens the throat is perfectly plain: in others tinged with rusty; in still others sprinkled with small purplish spots, while in one bird (No. 17,083, La Paz, February 24, 1887), there is a rather large central patch of dull but iridescent purple. None of my females show any purplish on the crown.

This Hummingbird occurs throughout Lower California. In the Cape Region it is a resident species of somewhat local and peculiar distribution during the breeding season, although at other times of the year it apparently wanders over considerable areas in search of food. Thus Mr. Frazar found it abundant near La Paz in February and March and among the Victoria Mountains (opposite Carmen Island) during the latter month, but he failed to detect even a single specimen on the Sierra de la Laguna in May or early June. Mr. Belding characterizes it as "abundant in winter" about La Paz, but "not common at San José, Cape Saint Lucas, or Miraflores in April and May." At San José del Rancho Mr. Frazar saw only one or two in early July, but soon after the middle of that month a succession of heavy showers caused the vegetation to spring suddenly into leaf, and Costa's Hummers appeared in large numbers, coming, Mr. Frazar thought, from the region to the northward. They were most abundant about July 25, after which their numbers declined steadily. None were seen either here or at Triunfo in December.

According to Mr. Belding, Costa's Hummingbird seldom ranges above 2,000 feet altitude, and "thrives in barren, waterless tracts." Mr. Anthony, however, found it nesting in May, 1893, among the pines on San Pedro Martir at an altitude of 7,500 feet.[1] In the more southern portions of Lower California it breeds in January, February, and March, the earliest date on record being January 17, 1881, when Mr. Bryant found a nest containing "large young," on Santa Margarita Island.[2]

The general range of Costa's Hummingbird includes southern California, Arizona and western Mexico.

It is possible that *Selasphorus alleni* sometimes visits the Cape Region, for Mr. Frazar obtained an adult female in the Victoria Mountains opposite Carmen Island, on March 11, 1887.

Basilinna xantusi (Lawr.).

XANTUS'S HUMMINGBIRD.

Amazilia xantusii LAWRENCE, Ann Lyc. Nat. Hist. N. Y., VII. 1860, 109, 110 (orig. descr. of female; type from Cape St. Lucas).

Heliopaedica castaneocauda LAWRENCE, *Loc. cit.*, 145 (orig. descr. of male; crit; Cape St. Lucas).

A.[mazilia] xantusi SCLATER, Ibis, 1860, 309 (crit.; Cape St. Lucas).

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[1] Zoe, IV. 1893, 237.

[2] Proc. Calif. Acad. Sci., 2d ser., II. 1889, 289.

Heliopaedica xantusi GOULD, Mon. Troch., II. 1861, pl. 65 (descr.); Intr. Troch., 1861, 61. ELLIOT, Illustr. New and Unfig. N. Amer. Birds, I. 1869, pl. 22. BAIRD, BREWER, and RIDGWAY, Hist. N. Amer. Birds, II. 1874, 467, pl. 47, fig. 3 (descr. male and female; Cape St. Lucas). MULSANT and VERREAUX, Hist. Nat. Ois.-Mouches, II. 1876, 3 (descr.). JASPER, Birds N. Amer., 1878, 156, pl. 105, fig. 7 (Cape St. Lucas).

B.[*asilinna*] *xantusi* HEINE, Jour. Orn., 1863, 196 (crit.). COUES, Key N. Amer. Birds, 4th ed., 1894, 460, 461 (descr.; Cape St. Lucas.) RIDGWAY, Man. N. Amer. Birds, 2d ed., 1896, 318 (descr.; s. portion of Lower Calif.).

[*Hylocharis*] *xantusi* MULSANT and VERREAUX, Class. Troch., 1866, 38 (characters of the genus). SHARPE, Hand-list, II. 1900, 110.

Hylocharis zantusii GRAY, Hand-list, I. 1869, 151, no. 1,950.

Heliopaedica xantusii COOPER, Orn. Cal., 1870, 365 (descr.; Cape St. Lucas). COUES, Check List, 1873, 55, no. 273.

[*Heliopaedica*] *xantusii* COUES, Key N. Amer. Birds, 1872, 184 (descr.; Cape St. Lucas).

Heliopaedica xanthusi MULSANT, Ann. Soc. Linn. Lyon, nouv. sér., XXII. 1876, 207 (Mexique). MULSANT and VERREAUX, Hist. Nat. Ois.-Mouches, IV. 1877, 186 (synonymy).

Coeligena xanthusi MULSANT and VERREAUX, *Loc. cit.*, I. 1877, 190–192, pl. — (descr.; near Cape St. Lucas).

Basilinna xanthusi ELLIOT, Class. and Syn. Trochilidae, 1879, 227 (descr.; Cape St. Lucas). EUDES-DESLONGCHAMPS, Ann. Mus. Hist. Nat. Caen, I. 1881, 479–481 (descr.). BOUCARD, The Humming Bird, IV. 1894, 178, 179 (descr.; Cape St. Lucas).

Basilinna xantusi RIDGWAY, Proc. U. S. Nat. Mus., III. 1880, 6, 319 (Cape St. Lucas); V. 1883, 542, 543 (descr. Belding's nests and eggs from San José, April 23, and arroyo, n. of Santiago Peak, May 9); VI. 1883, 158, footnote (crit.; S. Lower Calif.); Nom. N. Amer. Birds (Bull. U. S. Nat. Mus., no. 21), 1881, 33, 65, 75, no. 347; Rep. U. S. Nat. Mus., 1889–1890, 1891, 369–371, pl. 44 (Cape district of Lower Calif.; descr. male, female, nest, and eggs; figures male and female from Pierce's Ranch, and nest from San José). COUES, Check List, 2d ed., 1882, 73, no. 407. BELDING, Proc. U. S. Nat. Mus., V. 1883, 542 (mountain cañons of Cape Region; Cacachiles Mt.; San José; descr. nest from San José, April 23); VI. 1883, 349 (Victoria Mts.). A. O. U., Check List, 1886, 227, no. 440. BRYANT, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 289, 290 (Cape Region; Comondu, etc.); Zoe, II. 1891, 191 (San José del Cabo). SALVIN, Cat. Birds Brit. Mus., XVI. 1892, 255 (descr.; Agua Escondida; mountains s. of La Paz; Triunfo; San José del Cabo). ALLEN, Auk, X. 1893, 142 (tropical type). BENDIRE, Life Hist. N. Amer. Birds, pt. II. 1895, 226, 227 (Cacachiles Mts.; San José; near Santiago Peak, etc.; descr. Belding's nests and eggs).

Xantus's hummingbird BRYANT *Loc. cit.*, 198 (Victoria Mts.).

[*Basilinna*] *xanthusi* DUBOIS, Synop. Avium, fasc. II. 1900, 139 (Basse-Californie).

Seasonal variations: — Males. The series collected by Mr. Frazar includes specimens taken every month of the year excepting October and January. The summer and autumn birds are by far the brightest colored, having the green of the back quite pure; the black of the forehead, sides of head and chin, deep velvety often glossed with violet or blue; the metallic green of the throat, clear and brilliant; the cinnamon rufous of the under parts, rich and pure. The spring birds (March, April, and May), are uniformly much duller and paler, the green of the back being much tinged with ashy or rusty, and the black of the head with brown, while the green of the throat is muddy in tone and but slightly iridescent. One bird (No. 17,031, Triunfo, April 11, 1887) has the black of the head confined to the auriculars, and the green of the throat to a few central spots, the rest of the under parts being dull cinnamon rufous, and the entire upper parts dull green with most of the feathers tipped with rusty cinnamon. This specimen is evidently immature and probably in juvenal plumage. The fact that it is the only male in the entire series which does not have the whole throat greenish and the forehead, cheeks, and lores black or dark brownish, would seem to indicate that young birds acquire the fully adult plumage with their first complete moult.

Baird, Brewer, and Ridgway describe and figure the male of this species as having "a distinct white stripe from bill, through and behind the eye." Coues says[1] that this stripe passes "through the eye." Elliot implies that it is situated as in *B. leucotis*, that is, "above and behind the eye." Ridgway states[2] that it is "behind eye." In all of the seventy males in my series it starts immediately above the middle of the eye, and curving down behind it extends straight backward along the side of the head for about half an inch, impinging closely on the eye both above and behind the upper eyelid.

Another discrepancy in the descriptions just referred to is in respect to the color of the bill. Baird, Brewer, and Ridgway say "whole upper mandible apparently dusky; base of lower, red:" Coues, "flesh-colored, black tipped;" Elliot, "red, tip black." In my dried specimens the basal half to three-fourths of the upper mandible and the basal three-fourths to seven-eighths of the lower mandible are flesh-colored, the remainder of both mandibles being dark brown.

Females. As with the males, the spring specimens are much paler and duller than the summer ones. Some of the latter have the top and sides of head, the upper tail coverts, and the middle pair of tail feathers strongly tinged with cinnamon. The superciliary stripe is often nearly pure white in early spring birds. Ridgway says[3] that the throat of the female is either "with or without green spots." In my series of forty-one females not one shows the slightest trace of green spotting on the throat.

This Hummingbird is peculiar to Lower California, but it is not strictly confined to the Cape Region, for Mr. Frazar found it common at a point about one hundred and fifty miles north of La Paz among the mountains opposite Carmen Island in latitude 26°, and Mr. Bryant has traced its extension still farther northward to about latitude 29°. It seems to be most abundant, however, in the mountains south of La Paz, especially on the Sierra de la Laguna, where it ranges from the highest elevations down to the lower limits of the oaks among the foothills. It also occurs — at least sparingly and locally at certain seasons — in the low arid country near the coast, for Mr. Frazar took a male at La Paz on February 11, and saw upward of a dozen at San José del Cabo in September. At the latter place, Mr. Belding found it "common in orchards" about the last of April, 1882. Among the mountains it shows a marked preference for cañons, especially such as have pools or small streams of water. Mr. Belding says that "in winter" it is "found only in mountain cañons," but Mr. Frazar's experience was exactly the reverse of this, for during his winter visit to the Sierra de la Laguna (November 27–December 2), the "whole top of the cold, sleety mountain was alive with Xantus's Hummers, which seemed to be attracted there by an abundant shrub covered with *dry* yellow blossoms, whereas in May and June they were confined quite closely to the cañons." The truth of the matter probably is that their movements, like those of most other members of this family, are dependent largely on the presence or absence, at any given locality or season, of the flowers on which they feed.

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[1] Key N. Amer. Birds, 4th ed., 1894, 460.

[2] Man. N. Amer. Birds, 1887, 318.

[3] *Loc. cit.*

A nest found at San José del Rancho, on July 28, was placed at the extremity of a slender, drooping oak twig, about eight feet above the ground. One side is built against and around the main stem (here only .12 inches in diameter), and the bottom rests securely on a terminal fork, from the ends of which hang a number of dry, bleached oak leaves, apparently of the previous year's growth. The chief, if not only, material composing the walls of this nest consists of small, woolly leaves of a pale sage-green color, intermixed with reddish-brown, catkin-shaped objects, which appear to be made up of numerous minute seed vessels attached in double, triple, or quadruple rows or clusters to stems an inch or more in length. The entire outer surface of the nest is wrapped with a net-work of spider-web silk so fine as to be well-nigh invisible but sufficiently strong and tautly drawn to give the walls a firm, smooth outline. The interior is not lined save at the bottom, which is furnished with a soft bed of whitish down, evidently that of some bird. This nest measures externally 1.60 inches in diameter by 1.65 in depth; internally, .73 inches in diameter by .50 in depth.

Tyrannus vociferans Swains.

Cassin's Kingbird.

Tyrannus vociferans Belding, Proc. U. S. Nat. Mus., V. 1883, 541 (Cape Region); VI. 1883, 348 (Laguna). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 290 (Cape Region).

Mr. Frazar found Cassin's Kingbirds abundant at La Paz in February, and early March, when they seemed to be passing northward. They were numerous again, on the return migration, during the last week of August and first ten days of September, at San Jose del Cabo, but rare in December (18–25) at

San José del Rancho, where a few seen in July were apparently breeding, although no nests were discovered. None were met with by Mr. Frazar on the mountains, but in 1883 the species was seen "around the meadow at Laguna" by Mr. Belding.

According to Mr. Bryant *T. vociferans* is not at all common in the central and northern portions of the Peninsula. Mr. Anthony, who "found it nesting in live oaks and cottonwoods up to about 4,000 feet altitude, . . . thinks he has seen none after the middle of November" (Bryant), but in California the species is said to be resident as far north as Los Angeles county. It migrates as far south, however, as Guatemala. The closely allied *T. verticalis* has been recorded from the northern part of Lower California.

Myiarchus cinerascens pertinax (BAIRD).

LOWER CALIFORNIA FLYCATCHER.

Myiarchus mexicanus (not *Tyrannula mexicana* KAUP) BAIRD, Proc. Acad. Nat. Sci. Phila., 1859, 301 (Cape St. Lucas), 303 (crit.; Cape St. Lucas). COOPER, Orn. Cal., 1870, 316, 317, part (crit.; Cape St. Lucas).

M.[yiarchus] pertinax BAIRD, *Loc. cit.*, 303 (Cape St. Lucas; provis. name for bird of Lower Calif.). COUES, Key N. Amer. Birds, 1872, 171 (crit.; Cape St. Lucas).

[Pyrocephalus] mexicanus GRAY, Hand-list, I. 1869, 362, no. 5,519, part.

Myiarchus mexicanus, var. *pertinax* COOPER, *Loc. cit.*, 317 (crit.; Cape St. Lucas). BAIRD, BREWER, and RIDGWAY, Hist. N. Amer. Birds, II. 1874, 337, 339 (crit.; Cape St. Lucas).

[Myiarchus] cinerascens COUES, Key N. Amer. Birds, 1872, 171, part (crit.; Cape St. Lucas). DUBOIS, Synop. Avium, fasc. IV. 1900, 250, part (Mexique). SHARPE, Hand-list, III. 1901, 144, part.

Myiarchus cinerascens (not *Tyrannula cinerascens* LAWRENCE) COUES, Proc. Acad. Nat. Sci. Phila., 1872, 69, 70, part (crit.; Cape St. Lucas); Check List, 1873, 51, no. 248, part. COUES and STREETS, Bull. U. S. Nat. Mus., no. 7, 1877, 12 (Pichilinque Bay; Cape St. Lucas). RIDGWAY, Nom. N. Amer. Birds (Bull. U. S. Nat. Mus., no. 21), 1881, 31, no. 313, part. BELDING, Proc. U. S. Nat. Mus., V. 1883, 541 (Cape Region). A. O. U., Check List, 1886, 232, no. 454, part. SCLATER, Cat. Birds Brit. Mus., XIV. 1888, 248, 249, part (La Paz; Cape St. Lucas). SALVIN and GODMAN, Biol. Centr.-Amer., Aves, II. 1889, 91, part (synonymy). BRYANT, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 290, part at least (Lower Calif.).

Myiarchus crinitus, var. *cinerascens* BAIRD, BREWER, and RIDGWAY, *Loc. cit.*, 337, part (Cape St. Lucas).

Myiarchus cinerescens (err. typ.) COUES, Check List, 2d ed., 1882, 69, no. 375, part.

M.[yiarchus] cinerescens (err. typ.) COUES, Key N. Amer. Birds, 4th ed., 1894, 436, part (crit.; Cape St. Lucas).

M.[yiarchus] cinerascens RIDGWAY, Man. N. Amer. Birds, 2d ed., 1896, 333, part.

My specimens from the Cape Region differ rather constantly from those from western Mexico and the United States in having longer as well as usually stouter bills. They are also almost invariably grayer above, especially on the crown and nape, and less yellowish on the abdomen, crissum, under tail coverts, and flanks. The grayish on the nape is often so pronounced as to form an obscure but noticeable band or collar. In autumnal plumage the abdomen, flanks, crissum, and under tail coverts are primrose yellow, the back faintly tinged with olive, the light edging of the secondaries and wing coverts slightly olivaceous; otherwise this plumage does not differ materially from that of spring.

The peculiarities above mentioned seem to me sufficiently pronounced to entitle this bird to subspecific separation from *cinerascens*. Baird as long ago as 1859 remarked the "rather stouter bill" which, he adds, "appears to be a constant character, and may one day cause its [the Lower California bird's] separation as a species. (*M. pertinax*, Baird)." Hence the form is already supplied with a name under which I have ventured to reinstate it here.

This Flycatcher is resident in the Cape Region from La Paz southward, but Mr. Frazar saw only a very few at San José del Cabo, and none on the Sierra de la Laguna. Its favorite haunts are arid, cactus-grown plains in the low country near the coast, but it also frequents thickets, where they are to be found.

Just how far to the northward on the Peninsula *pertinax* ranges before merging into or giving place to true *cinerascens* I am unable to state. Mr. Bryant, who does not discriminate between the two forms, says that the Ash-throated Flycatcher is "one of the most generally distributed species found in Lower California."

Sayornis saya (Bonap.).

Say's Phoebe.

Sayornis sayi Belding, Proc. U. S. Nat. Mus., V. 1883, 541 (Cape Region).
Sayornis saya Bryant, Proc. Calif. Sci., 2d ser., II. 1889, 290 (Cape Region).

Say's Phoebe occurs in the Cape Region only during winter, and even then it is apparently rare. Mr. Frazar took but three specimens, all at La Paz, in February. The species breeds in the northern portion of the Peninsula, for Mr. Anthony found some nests "in old mines and tunnels at Valladares, frequently at a depth of twenty feet in a shaft" (Bryant). In California it is resident as far north as Sebastopol. It ranges northward in summer along the Yukon River to the Arctic Circle, and southward in winter, on the plateau of Mexico, to Puebla and central Vera Cruz.[1]

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[1] A. O. U., Check List, 2d ed., 1895, 185.

Sayornis nigricans (Swains.).

BLACK PHOEBE.

Sayornis nigricans Baird, Proc. Acad. Nat. Sci. Phila., 1859, 301, 303 (Cape St. Lucas). Belding, Proc. U. S. Nat. Mus., V. 1883, 542 (Cape Region). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 290 (Cape St. Lucas; Cape Region).

Sayornis nigricans semiatra (Vigors) has been recently resuscitated by Mr. Nelson[1] and adopted as a good subspecies in the Tenth Supplement of the A. O. U. Check List. It is said to inhabit the "Pacific coast of Mexico and the United States from Colima to Oregon, including most of Arizona," and to have the "under tail-coverts pure white," while true *nigricans* is supposed to be confined to Texas, New Mexico, southeastern Arizona, and the interior and eastern parts of Mexico, and to have the corresponding feathers "white more or less broadly striped with dusky." From this it would appear that the bird of Lower California should be *semiatra*, but of my mature specimens (thirty-one in number) from the Cape Region, not one has the under tail coverts wholly immaculate, while the greater number possess conspicuous dusky shaft stripes on these feathers. The same thing is true in a general way of my examples from California, although one of the latter really does lack all trace of the markings just mentioned. Most of my numerous specimens from regions included within the habitat assigned to *nigricans* by Mr. Nelson undeniably show rather more of this dusky than is possessed by the average bird from the Pacific coast, but the difference seems to me too trifling and inconstant to deserve anything more than passing notice. Scarcely more important, in my estimation, is the fact that the Black Pewees of the Cape Region are usually, but by no means invariably, distinguishable from those of all other regions represented in my collection by their slightly larger (broader as well as longer) bills and comparatively faded, brownish coloring.

Mr. Belding gives this species as rare in the Cape Region. Mr. Frazar did not take it at La Paz, but further southward it is generally distributed and rather common at all seasons, ranging from San José del Cabo on the coast to the summit of the Sierra de la Laguna. It prefers the hilly country at the bases of the mountains, however, and is seldom seen far from water. Young on wing were met with at Triunfo in April. At Comondu Mr. Bryant found eggs "March 13, and full-fledged young April 9, 1888."

The Black Phoebe is found from Oregon to southern Mexico on the Pacific slope.

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[1] Auk, XVII. 1900, 124, 125.

Contopus richardsonii peninsulae Brewst.

Large-billed Wood Pewee.

[*Pyrocephalus*] *richardsoni* Gray, Hand-list, pt. I. 1869, 362, no. 5,510, part.
[*Contopus virens*] var. *richardsonii* Coues, Key N. Amer. Birds, 1872, 174, part.
Contopus virens, var. *richardsonii* Coues, Check List, 1873, 53, no. 255 a, part.
Contopus richardsoni Ridgway, Nom. N. Amer. Birds (Bull. U. S. Nat. Mus., no. 21), 1881, 31, no. 321, part.
Contopus virens richardsoni Coues, Check List, 2d ed., 1882, 70, no. 383, part.
Contopus richardsonii A. O. U., Check List, 1886, 234, no. 462, part.
Contopus richardsonii peninsulae Brewster, Auk, VIII. 1891, 144, 145 (orig. descr.; types from Sierra de la Laguna and Triunfo). A. O. U. Comm., Auk, IX. 1892, 106, no. 462 a; Check List, 2d ed., 1895, 187, no. 462 a. Ridgway, Man. N. Amer. Birds, 2d ed., 1896, 598 (descr.; S. Lower Calif.).
C.[*ontopus*] *v.*[*irens*] *richardsoni* Coues, Key N. Amer. Birds, 4th ed., 1894, 440, part.
Horizopus richardsonii peninsulae Oberholser, Auk, XVI. 1899, 333 (synonymy).
[*Contopus virens*] var. *peninsulae* Dubois, Synop. Avium, fasc. IV. 1900, 249 (Basse-Californie).
[*Horizopus*] *peninsulae* Sharpe, Hand-list, III. 1901, 142.

This near ally of *C. richardsonii* was discovered by Mr. Frazar on the Sierra de la Laguna, where it appeared about the middle of May, the males arriving nearly two weeks in advance of the females. It soon became very common, frequenting open places in the woods, and usually taking its station at the extremity of some dead branch. Its note is "a sharp, cutting *pee-ee-e*, the second syllable with a falling, the last with a rising, inflection." On June 9 while descending the mountain Mr. Frazar found these Flycatchers common to its base as well as afterwards at Triunfo and San José del Rancho. An adult female killed on June 20 at Triunfo was incubating, but no nests were found.

The Large-billed Wood Pewee has not been reported as yet from anywhere outside the Cape Region, but if, as the above evidence indicates, it is a migratory bird, it must also occur in Mexico and Central America.

Mr. Bryant records *C. richardsonii* from San Sebastian and a few localities in the northern part of Lower California.

Empidonax difficilis Baird.

Western Flycatcher.

(?) *Empidonax difficilis* Belding, Proc. U. S. Nat. Mus., V. 1883, 542, part (Cape Region); VI. 1883, 348, part (Victoria Mts.). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 291, part (Cape Region).

Of true *E. difficilis* I have seen only six Lower California specimens, all of which were collected by Mr. Frazar, — one at Santiago on November 15, the other five at San José del Rancho in December. Mr. Belding's mention of *difficilis* as "rare" may refer partly or wholly to the next species, which, of course, had not been separated at the time Mr. Belding's papers were written.

It is not probable that *E. difficilis* breeds anywhere in the Cape Region, although it may possibly do so in the extreme northern portions of the Peninsula. According to Mr. Bryant, it has been met with by Mr. Anthony at Valladares, during the autumnal migration, and by Mr. Belding in wooded cañons north of San Pedro Martir in May. It is abundant in summer throughout most of California and regularly ranges northward into British Columbia, while a single specimen has been taken at Sitka, Alaska.[1] In winter, it is said to go as far southward as Costa Rica.

Empidonax cineritius Brewst.

St. Lucas Flycatcher.

Empidonax flaviventris Cooper, Orn. Cal., 1870, 328, 329, part (Cape St. Lucas). Coues, Check List, 1873, 53, no. 259, part.

[*Empidonax*] *flaviventris* Coues, Key N. Amer. Birds, 1872, 175, 176, part.

Empidonax difficilis Ridgway, Nom. N. Amer. Birds (Bull. U. S. Nat. Mus., no. 21), 1881, 31, no. 323, part. (?) Belding, Proc. U. S. Nat. Mus., V. 1883, 542, part (Cape Region); VI. 1883, 348, part (Victoria Mts.). A. O. U., Check List, 1886, 234, 235, no. 464, part. (?) Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 291, part (Cape Region, etc.).

Empidonax flaviventris difficilis Coues, Check List, 2d ed., 1882, 71, no. 389, part.

Empidonax cineritius Brewster, Auk, V. 1888, 90, 91 (orig. descr.: types from La Laguna). A. O. U. Comm., Suppl. to Check List, 1889, 10; Check List, abridged ed., 1889, and 2d ed., 1895, no. 464.1. Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 291 (La Laguna; Comondu, etc.). Townsend, Proc. U. S. Nat. Mus., XIII. 1890, 137 (Cape St. Lucas). Allen, Auk, X. 1893, 142 (tropical type). Anthony, Zoe, IV. 1893, 238 (San Pedro Martir); Auk, XII. 1895, 140 (San Fernando), 390 (Cuymaca Peak, San Diego co., Calif.). Coues, Key N. Amer. Birds, 4th ed., 1894, 901 (descr.; Lower Calif.). Bendire, Life Hist. N. Amer. Birds, pt. II. 1895, 301 (La Laguna). Ridgway, Man. N. Amer. Birds, 2d ed., 1896, 599 (descr.; Lower Calif.).

E.[*mpidonax*] *f.*[*laviventris*] *difficilis ?* Coues, Key N. Amer. Birds, 4th ed., 1894, 442, part.

E.[*mpidonax*] *difficilis* Ridgway, Man. N. Amer. Birds, 2d ed., 1896, 340, part.

[*Empidonax bairdi*] var. *cineritia* Dubois, Synop. Avium, fasc. IV. 1900, 248 (California).

[*Empidonax*] *cineritius* Sharpe, Hand-list, III. 1901, 139.

Some of my winter specimens of this species appear to differ from those of *difficilis* only in respect to size and proportions and in having the general coloring duller — less olivaceous above and on the breast and sides, lighter yellow on the throat and abdomen. The bill of *cineritius* is almost invariably much narrower than that of *difficilis.*

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[1] Nelson, Rept. Nat. Hist. Coll. Alaska, 1887, 162.

The St. Lucas Flycatcher is resident in the Cape Region, where it is not uncommon. Mr. Frazar found it in the greatest numbers on the Sierra de la Laguna in May and early June. He also obtained specimens at San José del Rancho in July and at La Paz in February and March. Mr. Bryant has taken it at Comondu, and San Benito and Santa Margarita Islands, while on San Pedro Martir Mr. Anthony found it "very common all over the mountain, especially along the streams and in the willows. It was evidently nesting" at the time of his "visit in May, but no eggs were taken." He also states that it occurs sparingly near the mine and about the mission at San Fernando, where he thinks it nests "in the thick mesquite growth." It probably replaces *E. difficilis* in the breeding season throughout the greater part of Lower California.

Its summer range extends northward into southern California, where "in the pine growth on Cuymaca Peak," in San Diego County, "between the altitudes of 4,000 feet and 6,000 feet," Mr. Anthony took several specimens, which, without doubt, were breeding, during the latter part of June, 1895.

Empidonax griseus Brewst.[1]

Gray Flycatcher.

Empidonax obscurus (not *Tyrannula obscura* Swainson) Baird, Proc. Acad. Nat. Sci. Phila., 1859, 301, 303 (Cape St. Lucas). Belding, Proc. U. S. Nat. Mus., V. 1883, 542 (Cape Region). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 292 (Cape Region).

Empidonax griseus Brewster, Auk, VI. 1889, 87–89 (orig. descr.; types from La Paz; crit.; Triunfo; San José del Cabo). Bryant, *Loc. cit.* (La Paz; Triunfo; San José del Cabo). Bendire, Life Hist. N. Amer. Birds, pt. II. 1895, 320, 321 (near La Paz; Triunfo; San José del Cabo).

Mr. Frazar found the Gray Flycatcher at La Paz in February and March; at Triunfo in April and December; at San José del Rancho in December; and at San José del Cabo in October and November. His latest spring specimen is dated April 21, his earliest autumnal bird October 29. Mr. Belding mentions *E. obscurus* (= *wrightii*)[1] as "rare in summer," but this statement requires confirmation. Mr. Frazar did not take *E. wrightii* at all, and his experience with *E. griseus* furnishes no evidence that the latter passes the summer in the Cape Region. To the northward Mr. Bryant has taken it on Santa Margarita Island in February and at Comondu in March, but he does not mention seeing it after the latter month, and Mr. Anthony apparently failed to detect it at any season. Hence it becomes an interesting question where the numerous birds which winter in the Cape Regions breed.

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[1] In retaining this name I have acted in opposition to the advice of my friend, Mr. Nelson, who considers it a synonym of *E. canescens* Salvin and Godman. The plate and description of the latter in the Biologia Centrali-Americana certainly seem to fit my bird closely. When I visited England in 1891, however, I took with me either the types or typical specimens of most of the Mexican birds which I had up to that time described, and showed them to Mr. Salvin. My impression is that *E. griseus* was among the number, and that Mr. Salvin passed it as distinct from *canescens.* It is not improbable that I am mistaken in so thinking, but until the matter can be definitely settled by actual comparison of specimens, it seems to me wiser to retain the name *griseus* (published two months later than *canescens*) rather than to adopt the name *canescens* at the risk, however slight, of having to change back again later.

E. griseus nests commonly in southern Arizona, and according to Mr. Nelson as far south in the interior of Mexico as the southern extremity of the table land. I have seen perfectly typical examples which were collected in Los Angeles county, California, by Mr. Grinnell, who reports that the species is apparently resident in this county, being found in small numbers in the neighborhood of Pasadena and El Monte in autumn, winter, and spring, and not uncommonly in summer, at elevations of from 7,500 to 8,500 feet "in one limited locality, on the slopes of Mt. Waterman," where full-fledged young were obtained as early as July 11, 1897.[2]

Pyrocephalus rubineus mexicanus (SCL.).

VERMILION FLYCATCHER.

Pyrocephalus rubineus mexicanus BELDING, Proc. U. S. Nat. Mus., V. 1883, 542 (Cape Region). BRYANT, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 292 (Cape Region).

With the exception of a single specimen seen at La Paz on February 3, the Vermilion Flycatcher was observed by Mr. Frazar only at San José del Cabo in October and November, and at Santiago during the latter month. "It was confined to the vicinity of water and was not common." Mr. Bryant "met with it only in the latitude of Comondu, usually in cultivated gardens." These facts indicate that it is chiefly restricted to the southern portions of the Peninsula, although it is known to occur in southern California as far north as Ventura County. Its southward range extends to Guatemala. It probably breeds in the Cape Region of Lower California, but of this there is, at present, no definite proof.

Aphelocoma californica hypoleuca RIDGW.

XANTUS'S JAY.

Cyanocitta californica (not *Garrulus californicus* VIGORS) BAIRD, Cat. N. Amer. Birds, 1859, no. 437, part; Proc. Acad. Nat. Sci. Phila., 1859, 301 (Cape St.

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[1] Since writing the above, I have examined two specimens (No. 86,335 and No. 86,336, Coll. U. S. Nat. Mus.) which were taken by Mr. Belding at La Paz, one on December 18, 1881, the other on January 5, 1882. Both prove to be typical *griseus*.

[2] Grinnell, Pub. II. Pasadena Acad. Sci., 1898, 31.

Lucas), 305 (crit.; Cape St. Lucas). COOPER, Orn. Cal., 1870, 302, 303, part (crit.; Cape St. Lucas). BAIRD, BREWER, and RIDGWAY, Hist. N. Amer. Birds, II. 1874, 288–290, part (crit.; Cape St. Lucas).

[*Cyanurus*] *californicus* GRAY, Hand-list, pt. II. 1870, 4, no. 6,092, part.

[*Aphelocoma floridana*] var. *californica* COUES, Key N. Amer. Birds, 1872, 166, part (Pacif. coast).

Aphelocoma floridana, var. *californica* COUES, Check List, 1873, 49, no. 236 b, part.

Aphelocoma californica (not *Garrulus californicus* VIGORS) RIDGWAY, Nom. N. Amer. Birds (Bull. U. S. Nat. Mus., no. 21), 1881, 30, no. 293, part; Proc. U. S. Nat. Mus., V. 1883, 541 (crit.; Lower Calif.). BELDING, *Ibid.* (Cape Region); VI. 1883, 348 (Victoria Mts.). A. O. U., Check List, 1886, 242, 243, no. 481, part. SALVIN and GODMAN, Biol. Centr.-Amer., Aves, I. 1887, 493, part (Cape St. Lucas).

Aphelocoma floridana californica COUES, Check List, 2d ed., 1882, 67, no. 356, part.

A.[*phelocoma*] *californica hypoleuca* RIDGWAY, Man. N. Amer. Birds, 1887, 356 (orig. descr., "based on many specimens from Cape St. Lucas, La Paz, and contiguous localities").

Aphelocoma californica hypoleuca, A. O. U. COMM., Suppl. to Check List, 1889, 11; Check List, abridged ed., 1889, and 2d ed., 1895, no. 481 a. BRYANT, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 24 (descr. nest and eggs from San Ignacio), 293 (Cape Region and n. to 28°). COUES, Key N. Amer. Birds, 4th ed., 1894, 901 (descr.; vicinity of Cape St. Lucas). BENDIRE, Life Hist. N. Amer. Birds, pt. II. 1895, 378 (vicinity of Cape St. Lucas; descr. eggs taken by Xantus near Cape St. Lucas).

[*Aphelocoma californica*] var. *hypoleuca* DUBOIS, Synop. Avium, fasc. VII. 1901, 512 (Basse-Californie).

The characters enumerated by Mr. Ridgway are fairly well maintained in the large series of specimens of Xantus's Jay collected by Mr. Frazar, although none of them are quite constant. As a rule, however, *hypoleuca* is considerably smaller than *californica*, the bill is longer as well as stouter, the blue, especially on the wings and tail, is much lighter, and the under parts are whiter. There is also usually more blue on the sides of the head, especially over the auriculars.

Individual variations: — The blue of the head varies greatly in shade, ranging from marine blue to china blue. In some of the June specimens it is entirely worn off most of the feathers of the head, excepting those on the forehead and sides of the crown, the remainder of the head above and on the sides being plain brown. The blue of the wings and tail is much less variable than that of the head. The brown of the back and scapulars is pale and grayish in some birds, in others deep and rich with a tinge of sepia. A few specimens have the scapulars and hind back strongly bluish: many show exceedingly faint dusky bars on the tail, as well as sometimes on the wing coverts.

Juvenal plumage: — *Male* (No. 16,528, Triunfo, June 27, 1887). Upper parts, with the sides of the head and neck, plain, dull drab, tinged with plumbeous on the crown and forehead, with gray on the rump and upper tail coverts; a short, inconspicuous, grayish stripe above the eye extending from its anterior corner backwards about half an inch; under parts grayish white, bordered on the sides of the throat and breast with brownish drab, which also forms a narrow and rather obscure band across the breast; wings and tail as in the adult, but with the greater covert tipped, and some of the middle and lesser coverts tinged, with drab. Bill, tarsi, and feet black.

Autumnal plumage: — This differs only slightly, if at all, from the nuptial plumage. Indeed, the birds which I take to be adult are practically inseparable from unworn spring specimens. Others, probably young, have the blue paler, the brown of the scapulars and back duller or more ashy.

This, the only Jay known to inhabit the Cape Region, is very common and generally distributed there, being found almost everywhere from the sea-coast to the tops of the highest mountains. About La Paz it nests in March, but the birds seen by Mr. Frazar on the Sierra de la Laguna in May and early June were in flocks and showed no signs of having bred that season or of being about to breed. They probably leave the mountains before the beginning of winter and seek more sheltered haunts in the valleys and foothills at lower elevations, for Mr. Frazar did not find a single individual on the Sierra de la Laguna during his second visit, in the latter part of November, 1887.

Mr. Bryant found a nest of this Jay "a few miles southward from San Ignacio on April 12, 1889. The nest was built about three metres high in a green acacia near the trail. The female was sitting, and did not fly until preparations for climbing the tree had commenced. The nest was in quite an exposed situation amongst scant twigs on a horizontal branch. It is composed of small loosely laid dry twigs, and a shallow receptacle lined with fibre and horsehair.

"The eggs, three in number (set No. 899, coll. of W. E. B.), contained small embryos. They are more finely spotted than some similar jay's eggs, with shell spots of pale lilac-gray and surface spots of pale olive-green. The ground color is dull, pale glaucous green. They measure 27.5 × 20.5; 27.5 × 21; 27 × 21 millimetres."

Xantus's Jay is confined to Lower California. It was first seen by Mr. Bryant "among the mangroves of Magdalena Island, and along the mangrove-bordered *estero* to San Jorge, and northward as far as lat. 28°." On San Pedro Martir mountain it is replaced by *obscura*, a race doubtfully distinct from *californica*. The latter bird is said to occur still further to the northward on the Peninsula, "about Ensenada and to the eastward."[1]

Corvus corax sinuatus (Wagl.).

American Raven.

Corvus corax carnivorus (not *Corvus carnivorus* Bartram) Belding, Proc. U. S. Nat. Mus., V. 1883, 541 (Cape Region); VI. 1883, 348 (Victoria Mts.).

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[1] Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 293.

Corvus corax sinuatus BRYANT, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 293 (Cape Region).
Raven, BRYANT, Zoe, II. 1891, 191 (San José del Cabo).

Although the Raven is common throughout the Cape Region during the entire year it is most numerous there in winter, according to Mr. Frazar. Probably a good many migrants come down from the North at that season, or the apparent increase may be due merely to concentration at points where food is abundant. In December Mr. Frazar observed twenty or thirty gathering nightly to roost in a tree on the summit of the Sierra de la Laguna.

Mr. Bryant says that the Raven extends throughout "the entire peninsula and shore islands." Its general range on the Pacific coast stretches from Guatemala to Alaska.

Molothrus ater (BODD.).

COWBIRD.

A male Cowbird taken by Mr. Frazar at Santiago on November 22, 1887, seems to be perfectly typical *ater*, which has not been hitherto reported from any portion of Lower California. Mr. Belding gives several records of the occurrence of this form in eastern California, but adds that "no Cowbirds have ever been collected in California, west of the Sierra Nevada, as far as I am aware."[1] *M. ater* is said to migrate into Mexico, but just how far to the southward is not accurately known.

Molothrus ater obscurus (GMEL.).

DWARF COWBIRD.

Molothrus ater obscurus BELDING, Proc. U. S. Nat. Mus., V. 1883, 546 (San José del Cabo), 547 (San José). BRYANT, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 294 (San José del Cabo). BENDIRE, Rept. U. S. Nat. Mus., 1892–1893, 1895, 598 (San José del Cabo); Life Hist. N. Amer. Birds, pt. II. 1895, 441 (San José del Cabo).

This is the characteristic Cowbird of the Cape Region, where, however, it appears to be comparatively uncommon and is not known to breed. Mr. Frazar met with it only in autumn at San José del Cabo and Santiago, taking his first specimen on September 30 at the former locality, where Mr. Belding had previously noted it in April and May, 1882. Mr. Bryant does not appear to have observed it to the northward, but says that Mr. Anthony "saw what he supposes was this Cowbird at San Quintin." It is common in southern Arizona, but is not known to enter California.

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[1] Occ. Papers Calif. Acad. Sci., II., Land Birds Pacif. District, 1890, 118.

Xanthocephalus xanthocephalus (Bonap.).

YELLOW-HEADED BLACKBIRD.

Xanthocephalus icterocephalus Belding, Proc. U. S. Nat. Mus., V. 1883, 546 (San José del Cabo).

Xanthocephalus xanthocephalus Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 294 (San José del Cabo).

This Blackbird is known to occur in the Cape Region only in autumn, winter, and early spring. At San José del Cabo Mr. Belding found it rare in April, and Mr. Frazar noted it as not common in September and October. The latter observer also met with a number of birds at Santiago in November and a single individual at La Paz on February 15.

Mr. Bryant does not mention seeing the Yellow-headed Blackbird in the central or northern portions of Lower California, but cites Mr. Anthony as authority for the statement that it is "very common along the coast during migrations." It probably does not pass the summer anywhere on the Peninsula, for it is not known to breed south of Santa Barbara in California. It migrates into western Mexico, at least as far to the southward as Mazatlan.

Agelaius phoeniceus sonoriensis Ridgw.

SONORAN RED-WING.

Agelaius —— Baird, Proc. Acad. Nat. Sci. Phila., 1859, 301, 305 (San José).

Agelaeus phoeniceus (not *Oriolus phoeniceus* Linnaeus) Belding, Proc. U. S. Nat. Mus., VI. 1883, 350 (La Paz and s.).

Agelaius phoeniceus (not *Oriolus phoeniceus* Linnaeus) Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 294 (San José del Cabo).

The form *sonoriensis*, as far as my material shows, is very distinctly characterized, especially in the female, which differs markedly at all seasons from the female of *phoeniceus*. The six specimens collected by Mr. Frazar agree closely in size and general coloring with specimens from northwestern Mexico, excepting that all three of my Lower California females have the capistrum, throat, and breast strongly tinged with salmon pink, a peculiarity which I do not find in Mexican birds.

Mr. Frazar saw the first Sonoran Red-wings at San José del Cabo on August 28, when an adult male was killed from a flock of about eighty. None were observed afterwards until October 30, when two old males were seen flying over the river. On November 4 two were shot from a flock of six, all of which seemed to be young birds. At Santiago one was seen on November 15, and five were noted on the 27th. Mr. Belding's mention of *A. phoeniceus*, as rare in the "vicinity of La Paz and southward," doubtless relates to this form, which is replaced by the closely allied subspecies *neutralis* in the northern portions of the Peninsula, where *A. tricolor* and *A. gubernator californicus* have also been found.

Sturnella magna neglecta (Aud.).

WESTERN MEADOWLARK.

Sturnella neglecta Belding, Proc. U. S. Nat. Mus., VI. 1883, 351 (La Paz and s.).
Sturnella magna neglecta Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 294 (San José del Cabo; La Paz).

Mr. Belding gives the Western Meadowlark as "rare" in the "vicinity of La Paz and southward." It was met with by Mr. Frazar only at San José del Cabo and Santiago. At the former place it arrived on October 14, after which a few were seen at intervals during the remainder of October and the first half of November. At Santiago a solitary bird was killed on November 19. In the central and northern portions of the Peninsula it has been found "upon a narrow strip of sand-hills between the *estero* and the ocean, about seventy miles from Magdalena Island"; near Pozo Grande; "within a few days' travel of San Quintin"; on Cerros Island; and near San Rafael (Bryant). At San Fernando, according to Mr. Anthony, it is "not uncommon during winter at the mission, but very rare, if present, in summer."[1] These facts indicate that the bird occurs rather generally but sparingly and more or less locally over the entire Peninsula, probably breeding in the central and northern portions, and visiting the Cape Region only in autumn and winter. Still further northward it is common from southern California to British Columbia, and it even reaches Alaska (Sitka), according to Mr. J. K. Lord.[2] Southward it ranges "through central and western Mexico to Guanajuato and Jalisco."[3]

Icterus parisorum Bonap.

SCOTT'S ORIOLE.

Icterus parisorum Baird, Proc. Acad. Nat. Sci. Phila , 1859, 301 (Cape St. Lucas), 305 (descr. female; Cape St. Lucas). Cassin, *Ibid.*, 1867, 54 (Lower Calif.). Baird, Brewer, and Ridgway, Hist. N. Amer. Birds, II. 1874, 189, 190 (abundant at Cape St. Lucas, with breeding habits). Belding, Proc. U. S. Nat. Mus., V. 1883, 541 (Cape Region); VI. 1883, 348 (Victoria Mts.). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 295 (Cape Region). Bendire, Life Hist. N. Amer. Birds, pt. II. 1895, 473 (breeding habits in Cape Region).

In my large series of specimens of this Oriole, there is so much variation, affecting, apparently, adult as well as young birds, that it is impossible to describe the different plumages under the usual stereotyped headings. Both sexes seem to have two distinct phases of coloring, certainly common to all seasons, and having no obvious connection with the age of the individual. Thus a certain percentage of males, not greater, apparently, in autumn than during the breeding season, have the wings and tail light grayish brown, the rump and posterior under parts, as well as sometimes the entire upper parts also, dull orange-yellow, tinged with brown on the back. In such specimens the throat, jugulum, and breast are always black, although the sides of the neck are often pure olive-yellow. It is possible, of course, that this plumage is a mark of immaturity, but it occurs quite as frequently among breeding birds as with those taken in autumn, while several of the latter, which I take to be young, are distinguishable from others, certainly adult, only by having the feathers of the hind back tipped with ashy white, giving the plumage of this part a scaled appearance. Traces of this white tipping also occur on one or two of my spring specimens. Both young and old in autumn differ from spring birds in having the yellow of the rump and under parts deeper (gamboge rather than lemon) and the inner secondaries broadly and conspicuously bordered on their outer webs with pure white, this always extending around the tips of the feathers and backward a little way along the edges of the inner webs. The greater coverts, also, are much more broadly white-tipped than in spring.

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[1] Auk, XII. 1895, 140.

[2] Naturalist in Vancouver Island and British Columbia, II. 1866, 147.

[3] A. O. U., Check List, 2d ed., 1895, 206.

Mr. Ridgway describes the adult female of this species[1] as wholly without black, but all of my fifteen spring specimens from Lower California have the entire throat, jugulum, and breast unmixed black, of a duller shade, however, than in the male. Three of them also have the whole top and sides of the head and nape black, and the back dark slaty brown without admixture of olive or greenish. The others have the head above and on the sides, as well as the sides of the neck, more or less olivaceous, while in two or three the chin and sides of the throat are also mixed with grayish or olive. Several spring females in my collection and that of the American Museum, from Arizona and northwestern Mexico, as well as two autumnal females from Lower California, agree closely with Mr. Ridgway's description. A third autumnal female from Lower California differs from these specimens only in having a cluster of black spots on the breast. The nine females which make up the balance of my autumnal series from Lower California do not differ appreciably from the spring birds of the same sex above described, excepting that, like the males in autumn, they have the white bordering the wing coverts and secondaries much broader and purer than in spring, and the black feathers of the head, throat, etc., more or less tipped with olivaceous.

The case may be stated more briefly and generally as follows: — Eight of the forty-seven spring males and four of the twenty-five autumnal males have the under parts as well as the top of the head and the back more or less olivaceous. Three of the twenty-four spring females are wholly without black on the head, throat, and breast. Two of the thirteen autumnal females lack all traces of black on these parts, while a third has only a cluster of black spots on the breast.

Juvenal plumage: — Both sexes closely resemble the plain olive phase of the adult female, from which they differ only in having the upper parts browner, the light edging on the wing coverts and secondaries much broader and more or less tinged with yellowish. Some of the males show a few black feathers, possibly of the coming autumnal plumage, on the breast and throat.

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[1] Man. N. Amer. Birds, 1887, 373.

General remarks: — Upon comparing spring specimens in full plumage from Lower California with others from Arizona and northwestern Mexico, I find two slight differences which seem to be correlated with geographical distribution. The yellow of the rump and under parts in the male of the Lower California bird is lemon, whereas in all my Arizona skins it is gamboge. The posterior outline of the black on the breast is also more clearly defined in the Lower California specimens than in those from Arizona. In the latter many of the posterior black feathers are tipped with yellow. Mexican examples appear to be intermediate in both these respects between the Arizona and the Lower California specimens. I do not find any constant differences in size or proportions between the birds from the several regions just mentioned. There is perhaps a greater tendency to black on the head, throat, etc., in the female from Lower California than in that from Mexico and Arizona, for, as already mentioned, all the *spring* females before me which wholly lack the black are from Arizona or western Mexico.

In the Cape Region Scott's Oriole is resident, but perhaps somewhat more numerously represented in summer than in winter. At the former season it is very generally distributed, occurring almost everywhere from the lowlands along the coast to the summits of the higher mountains. It shows a marked preference, however, for dry, barren country such as that about Triunfo, where Mr. Frazar met with it in the greatest numbers. On July 8 at Pierce's Ranch he found a nest " containing three young, nearly large enough to fly. This nest was made of the yellow fibre of palm leaves, and was lined with a few long, black horse-hairs. It was placed among the densest foliage of a fig-tree at a eight of about eight feet, and rested on a few small twigs, but seemed to be fastened only to some twigs above, from which it was suspended. It was not deep, for the heads of the young appeared above the upper edge."

Scott's Oriole has been found at various places in the central and northern portions of the Peninsula as well as near San Diego and Los Angeles, California, the locality last named being perhaps the most northern one to which it ever extends its summer range. In the mountain portions of Lower California it is said by Mr. Bryant, on the authority of Mr. Anthony, " to prefer the low hills near the coast south of San Quintin, where it nests in the thorny branches of the candlewood (*Fouquiera columnaris*)."

Scott's Oriole also breeds in southern Arizona, New Mexico, and western Texas. " In winter it passes southwards as far as Central Mexico in the States of Puebla and Vera Cruz; and Sumichrast includes it amongst the birds of the temperate and alpine regions of the latter State. It breeds, he says, in the temperate region, and is found as high as between 5,000 and 6,000 feet above the sea in the neighborhood of Orizaba, and at even higher altitudes in the plateau."[1]

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[1] Salvin and Godman, Biol. Centr.-Amer., Aves, I. 1887, 463, 464.

Icterus cucullatus nelsoni RIDGW.

ARIZONA HOODED ORIOLE.

Icterus cucullatus (not of SWAINSON) BAIRD, Proc. Acad. Nat. Sci. Phila., 1859, 301, 305 (Cape St. Lucas). BAIRD, BREWER, and RIDGWAY, Hist. N. Amer. Birds, II. 1874, 194, part (abundant at Cape St. Lucas, with breeding habits). BELDING, Proc. U. S. Nat. Mus., V. 1883, 541 (Cape Region); VI. 1883, 345 (Cape Region).

Icterus nelsoni SALVIN and GODMAN, Biol. Centr.-Amer., Aves, I. 1887, 472, 473 (La Paz; abundant and breeding at Cape St. Lucas).

Icterus cucullatus nelsoni BRYANT, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 295 (Cape Region); Zoe, II. 1891, 188 (San José del Cabo).

The characters pointed out by Mr. Ridgway are well maintained in the large series collected by Mr. Frazar, all of the males of which can be readily distinguished from Texas specimens by the absence of any pronounced orange tint in the yellow of the head, rump, and under parts. Most of my Lower California skins have the yellow of the under parts duller and that of the head with a more decided tinge of saffron, than in Arizona examples. In fact, the Lower California bird seems to represent the extreme type of divergence from true *cucullatus.*

Individual variations. Spring plumage: — Adult male. The yellow varies considerably in tint, especially on the head where it is often strongly tinged with saffron. This color seems to be confined to the tips of the feathers, for, as the season advances and the plumage wears, the head becomes nearly pure yellow. One bird in my series has an elongated patch of yellow on the inner web of each outer tail feather beginning about half an inch from its tip, and extending backward nearly three fourths of an inch. There is an immature (or perhaps dichromatic) phase of plumage of the male (corresponding to that of the Orchard Oriole), in which the bird resembles the adult male only in having the full black "hood," the coloring otherwise being almost precisely as in the female, although the yellow of the under parts is sometimes richer or less greenish than in the latter. My series contains three specimens illustrating this condition.

Adult female. One of my specimens (No. 16,497, Triunfo, April 13, 1887) has an obscure blackish patch in the middle of the breast. Traces of this exist in one or two others, but as a rule the under parts are essentially plain.

Autumnal plumage: — Adult male (No. 16,518, San José del Cabo, October 20, 1887). Yellow much deeper and browner than in spring birds — on the crown, sides of head and nape, rump and upper tail coverts, heavily overlaid with olive, on the breast and sides of the body with raw sienna; black of the head and breast pure; that of the back and scapulars nearly obscured by grayish olive which forms a broad tipping on all of the feathers; white edging of wing coverts, secondaries, etc., broader than in the spring bird and tinged with cream color; all the tail feathers tipped with brownish white. Another adult male taken on December 15, at Triunfo, is similar, but less brownish or olivaceous on the head, neck, and under parts.

Young female (No. 16, 496, Triunfo, December 7). Differing from the spring female in having the entire upper parts more olivaceous; the lower parts yellower; the greater and middle coverts, as well as the inner secondaries, more broadly tinged with white; the base of the upper mandible flesh colored to a little beyond (*i. e.*, anterior to) the nostril.

This Oriole occurs throughout Lower California, where it is a much commoner bird than the preceding species. Mr. Bryant has found it on Santa Margarita Island in January, and Mr. Frazar took a few specimens at La Paz in February, and others at Triunfo in December. The latter observer believes, however, that by far the greater number leave the Peninsula before winter, "returning about the middle of March." He saw only one individual on the Sierra de la Laguna, but observed many in the cañons at its base. The species was most numerously represented about Triunfo where it frequented trees near water, and began nest building late in June. The first eggs, a set of four, were found at San José del Rancho on July 14; during the following ten days, six nests and sets of eggs were obtained. Mr. Frazar notes three as the usual "clutch," but four of the nests which he took contain four eggs each.

The nests are essentially uniform in size and shape, and in these respects similar to the nest of the Baltimore Oriole, although smaller and decidedly shallower. All are largely composed of a fine, straw-colored, jute-like fiber firmly interwoven, and four contain only this material, but the fifth is lined with horsehair, and the sixth with cotton and a few feathers. One was attached to the under side of a palm-leaf, two to the branches of orange trees, three were in bushes, and one was suspended at the end of a drooping branch of some deciduous tree. They were placed at heights above the ground varying from four to eight feet. Mr. Xantus found a nest "on an aloe four feet high," another on the stem of a *Yucca angustifolia* six feet from the ground, a third in moss, "hanging out of a perpendicular bluff, on the sea-coast," and a fourth "in a convolvulus, on a perpendicular rock fifty feet high." [1]

The twenty-five eggs taken by Mr. Frazar vary considerably in size and shape. Some are ovate, others elongate ovate, and still others elliptical ovate. The ground color is creamy white; the markings are spots, blots, dashes, or irregular pen-like lines of lavender, light reddish or dark purplish brown, arranged chiefly about the larger ends. These eggs average .89 × .61 with extremes of .96 × 60, .94 × .64, .83 ×.64 and .85 × .58.

The Arizona Hooded Oriole is common in southern California and is found as far north as Santa Barbara. It also inhabits southern Arizona and western Mexico as far south as Mazatlan.

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[1] Baird, Brewer, and Ridgway, Hist. N. Amer. Birds, II. 1874, 194.

Scolecophagus cyanocephalus (Wagl.).

Brewer's Blackbird.

Scolecophagus cyanocephalus Belding, Proc. U. S. Nat. Mus., V. 1883, 546 (San José del Cabo), 547 (San José). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 295 (San José del Cabo).

Mr. Frazar took only two specimens of Brewer's Blackbird, the first at La Paz on February 15, the second at San José del Cabo on October 28; his notes also refer to a flock seen at the latter place on October 15. Mr. Belding, in the list of birds "found at San José del Cabo from April 1 to May 17," characterizes the species as "common, breeding," but this is almost certainly a mistake, for on the next page he states that it was "rarely seen in May." Mr. Bryant says nothing about its breeding in the central or northern portions of Lower California, but merely mentions two flocks seen near Comondu in March, 1888, and small flocks observed at San Ignacio about the middle of April, adding "Mr. Anthony has found them at times in small flocks on San Pedro Martir."

The latter observer has since reported that in 1893 they were "common in all of the lower valleys," about San Pedro Martir and that "at San Vicente a large colony had taken possession of the old olive trees at the abandoned mission and dozens of nests with eggs were seen on April 28. At La Grulla they were nesting in the pines in early May."[1] Mr. Anthony also found a few birds near San Fernando, where they "were probably nesting at the mission, as they were seen until the last of June."[2]

Brewer's Blackbird breeds throughout California, where it also winters, at least as far north as Contra Costa and Alameda counties. Its summer range on the Pacific coast extends into British Columbia, and it migrates south in winter to the table-lands of Mexico.

Carpodacus mexicanus ruberrimus Ridgw.

St. Lucas House Finch.

Carpodacus frontalis (not *Fringilla frontalis* Say) Baird, Proc. Acad. Nat. Sci. Phila., 1859, 301, 304 (Cape St. Lucas). Salvin and Godman, Biol. Centr.-Amer., Aves, I. 1886, 421, 422, part (crit.; Cape St. Lucas).

Carpodacus frontalis, var. *rhodocolpus* (not *Carpodacus rhodocolpus* Cabanis) Baird, Brewer, and Ridgway, Hist. N. Amer. Birds, I. 1874, 468, part (descr. Cape St. Lucas bird).

Carpodacus frontalis rhodocolpus Belding, Proc. U. S. Nat. Mus., V. 1883, 537 (Cape Region). Ridgway, *Ibid.* (descr. ad. males).

Carpodacus frontalis ruberrimus Ridgway, Man. N. Amer. Birds, 1887, 391, footnote (orig. descr.; provis. name for S. Lower Calif. bird, based on Cape St. Lucas specimen). BRYANT, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 23, 24 (descr. nest and eggs from Comondu), 297 (Cape Region). TOWNSEND, Proc. U. S. Nat. Mus., XIII. 1890, 137 (Cape St. Lucas).

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[1] Zoe, IV. 1893, 239.

[2] Auk, XII. 1895, 140.

C.[arpodacus] mexicanus ruberrimus RIDGWAY, *Loc. cit.*, 594.

Carpodacus mexicanus ruberrimus RIDGWAY, *Loc. cit.*, 592. BRYANT, *Loc. cit.*, 296 (Cape Region).

C.[arpodacus] ruberrimus McGREGOR, Condor, III. 1901, 13, 14 (dichromatism in birds from San José del Cabo).

Mr. Ridgway has claimed[1] that the House Finch of Lower California differs from *C. m. frontalis:* "(1) in the smaller general size, (2) rather more swollen bill, and (3) greater extension of the red." That the first and second of those characters are so variable as to be practically worthless, is shown conclusively by the large series collected by Mr. Frazar, but the extreme extension of the red is sufficiently constant in these specimens to fully warrant the recognition of the Lower California bird under the appropriate name which Mr. Ridgway has proposed.

I cannot, however, endorse the still more recent separation which Mr. Ridgway has made[2] of *Carpodacus mexicanus sonoriensis*, based on the bird of "Southern Sonora (north to Guaymas on the coast) and southeastern Chihuahua," which is said to differ from *ruberrimus* of Lower California only in having longer wings and tail and slightly smaller bill. It is true that, as a rule, my examples from the Cape Region are characterized by somewhat thicker or more swollen bills than are possessed by those which I have received from Guaymas and Alamos, Sonora, but the birds of the two regions, as represented in my collection, do not show (even by averages of measurements) the difference in respect to the length of the wings and tail which Mr. Ridgway has noted. I am therefore forced to regard them both as referable to the same form (*ruberrimus*).

Individual variations: — The males vary considerably in general size, and excessively in respect to the size and shape of the bill. The under tail coverts are always tinged with red, and in the majority of specimens this color extends well down over the abdomen, while in a few it spreads over the entire under parts, never, however, quite concealing the underlying white of the abdomen, anal region and under tail coverts nor obscuring the brown streaks on the sides. On the upper parts, the red invariably tinges the entire back as well as occasionally the sides of the head, excepting the lores. Its tint differs somewhat with different individuals and very considerably with season. In spring specimens it varies from poppy red to brilliant carmine, in autumn birds it is nearly uniform dull wine purple. Fully fifty per cent of my spring males and a few autumnal ones, also, show more or less yellow on the under parts, usually either on the breast or sides. Young males in autumn plumage are apparently not distinguishable from adults taken at the same season.

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[1] Man. N. Amer. Birds, 2d. ed., 1896, 391, footnote.

[2] Birds N. and Midd. Amer., pt. I. 1901, 135, 136.

Nearly half of my adult females have the throat, and occasionally the breast, also, strongly tinged with carmine or purplish.

Young in juvenal plumage do not differ appreciably from those of *frontalis*.

This is one of the most abundant birds of the Cape Region, throughout which it is very generally distributed, save on the higher mountains, where it was not seen by either Mr. Belding or Mr. Frazar. The latter found it building at Triunfo the last week in April. Young of the first brood were on wing and their parents laying a second time by the last week in June. One pair had taken possession of an old nest of the Arizona Hooded Oriole, which was attached to the under side of a palm leaf.

Mr. Bryant says that most of the nests of the St. Lucas House Finch which he found at Comondu "were in palm trees and well nigh inaccessible;" but one was on the "under side of a veranda awning of an *adobe* house" among the branches of a vine. This nest was "adapted to the space wherein it was built, and composed of such material as was nearest at hand," viz., "rootlets, a bit of rag and considerable wild cotton," with "a few soft shreds from plant stalks, a quantity of wild cotton, and lastly, some horsehairs" as lining.

The only nest obtained by Mr. Frazar was taken on June 20 at Triunfo. It was built under the thatch of a roof, resting on one of the cross-beams to which the thatch was tied. It is composed almost wholly of coarse cotton string intermixed with a few horsehairs and stems of weedy plants. The eggs, three in number, are not distinguishable from those of *C. m. frontalis*. They measure respectively: .69 × .52, .71 × .55, and .73 × .55.

According to Mr. Bryant and Mr. Anthony, *C. m. ruberrimus* is replaced in the northern portion of Lower California by *C. m. frontalis*, the latter extending at least as far southward as latitude 28° N. The limit of northward extension of *ruberrimus* does not seem to have been accurately determined.

Astragalinus psaltria (Say).

Arkansas Goldfinch.

Astragalinus psaltria Belding, Proc. U. S. Nat. Mus., V. 1883, 537 (Cape Region); VI. 1883, 347 (Victoria Mts.).

Spinus psaltria Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 298 (Cape Region).

The Arkansas Goldfinch is very common in winter in the Cape Region, particularly in the low country near the coast. Mr. Frazar did not see it later than April 23, except on the Sierra de la Laguna, where it was common the last week in April and rare in May. A few pairs may breed on this mountain, for in April, 1889, Mr. Bryant found nests at Comondu. Mr. Anthony states that it is "a common resident about the northern part of the peninsula reaching the lower slope of the mountain" at San Pedro Martir.[1]

[1] Zoe, IV. 1893, 240.

Astragalinus psaltria breeds abundantly in California, especially in the central portions, but does not appear to go much further northward. It visits northwestern Mexico in winter.

Astragalinus psaltria arizonae (Coues).

ARIZONA GOLDFINCH.

This form is represented in Mr. Frazar's collection by a perfectly typical specimen — a male taken at San José del Cabo on October 31, 1887. It has not been previously reported from any part of Lower California, although it has occurred once before on the Pacific Coast (Haywards, Alameda county, California[1]). I have long entertained doubts regarding the wisdom of recognizing it as subspecifically distinct from *psaltria*. It is true that the two are sufficiently unlike to be distinguished at a glance, but they intergrade and do not appear to have separate habitats. Thus from southern Arizona and New Mexico and northern Mexico, the supposed home of *arizonae*, my collectors have invariably sent me at least a dozen specimens of *psaltria* to one of *arizonae*. Indeed, there seems to be no known region or locality which yields exclusively or even chiefly the so-called *arizonae*. These facts suggest that the latter name applies merely to aberrant specimens of *psaltria* which represent more or less well marked approaches to the wholly black-backed *A. p. mexicanus*, or, as Mr. Ridgway has lately put the case, that *arizonae* "is scarcely a definite form, but is rather a series of specimens connecting *A. p. psaltria* and *A. p. mexicanus*, hardly two examples being exactly alike, and the geographic range not very definite."[2]

Spinus pinus (Wils.).

PINE SISKIN.

Chrysomitris pinus Belding, Proc. U. S. Nat. Mus., V. 1883, 537 (Cape Region).
Spinus pinus Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 298 (Cape Region).

Mr. Belding's mention of "one observed . . . in a flock of *A. psaltria*, with which, in California, the species frequently associates" remains the only record for the Cape Region. Neither date nor locality is given in this connection, but in his Land Birds of the Pacific District[3] Mr. Belding states that "a single specimen," presumably the one just referred to, was "shot at La Paz, in Lower California, in the winter of 1882."

On San Pedro Martir, according to Mr. Anthony, the Pine Siskin is "well distributed through the pines . . . but undoubtedly not common; no nests were found "[1] It is a common winter resident in the central and northern portions of California, and it has been found breeding on the higher mountains as far south as Los Angeles county. Its southward range in winter extends into northern Mexico.

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[1] Emerson, Zoe, I. 1890, 44.

[2] Birds N. and Midd. Amer., pt. I. 1901, 116.

[3] Occ. Papers Calif. Acad. Sci., II., Land Birds Pacif. District, 1890, 139.

Pooecetes gramineus affinis Miller.

Oregon Vesper Sparrow.

Pooecetes gramineus confinis (not of Baird) Belding, Proc. U. S. Nat. Mus., VI. 1883, 350 (La Paz and s.).

Poocaetes gramineus confinis (not of Baird) Bryant, Proc. Calif. Acad. Sci., 2d. ser., II. 1889, 298 (near La Paz).

Mr. Frazar did not meet with any form of the Vesper Sparrow in Lower California, but Mr. Belding gives *confinis* as "rare" in his list of birds found in the "vicinity of La Paz and southward" in the winter of 1882–83. To this Mr. Bryant adds, "Several were shot near La Paz by Mr. Belding in the winter. I found them near Pozo Grande and obtained one specimen at Llanos de San Julian. Mr. Anthony has noted it as not uncommon on the northwest coast." Mr. Belding asserts that *P. g. confinis* is a rather common winter visitor to California, and that the closely allied *P. g. affinis* has also been frequently taken there at the same season.[2]

Mr. Grinnell mentions both forms as "common winter" visitants in his List of the Birds of Los Angeles county.[3] Mr. Ridgway, however, apparently regards practically all the birds which inhabit or visit the Pacific coast district from Oregon to Cape St. Lucas as *affinis*, for the only record of *confinis* for this region which he accepts as valid in his latest work[4] is that by Mr. Grinnell as above cited.

Ammodramus sandwichensis alaudinus (Bonap.).

Western Savanna Sparrow.

Passerculus sandwichensis alaudinus Ridgway, Proc. U. S. Nat. Mus., V. 1883, 533, footnote (Cape St. Lucas). Belding, *Ibid.*, VI. 1883, 350 (San José del Cabo). Ridgway, *Ibid.* (crit.).

Ammodramus sandwichensis alaudinus Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 298, 299 (Cape St. Lucas; Cape Region).

A. s. alaudinus, like some of the other forms of the group to which it belongs, might be not inaptly termed a composite subspecies. In other words, it includes several well-marked but unnamed races which differ quite as much from one another and from the typical bird as does the latter from its nearest named and recognized allies. Mr. Frazar's specimens appear to represent two forms, — a small, slender-billed one which I take to be typical *alaudinus,* and a decidedly larger bird, which has a bill nearly as stout as that of *savanna.*

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[1] Zoe, IV. 1893, 240.

[2] Occ. Papers Calif. Acad. Sci., II., Land Birds Pacif. District, 1890, 140–142.

[3] Pub. II., Pasadena Acad. Sci., 1898, 36.

[4] Birds N. and Midd. Amer., pt. I. 1901, 184–187.

Mr. Frazar found the Western Savanna Sparrow in winter at La Paz, in autumn at Santiago and San José del Cabo. At the locality last named his first specimen was taken on August 27. During the next three weeks it was rather common, frequenting wet, grassy places. Mr. Bryant mentions seeing it only at San Jorge, where a few birds were observed in April. Mr. Anthony states that "a few winter about the base of San Pedro [Martir]."[1]

This subspecies occurs almost everywhere along the Pacific coast from northwestern Alaska to southern Mexico, breeding from California northward.

Ammodramus rostratus Cass.

Large-billed Sparrow.

Passerculus rostratus Cooper, Orn. Cal., 1870, 184 (Cape St. Lucas). Baird, Brewer, and Ridgway, Hist. N. Amer. Birds, I. 1874, 542, 543 (crit.; Cape St. Lucas). Belding, Proc. U. S. Nat. Mus., V. 1883, 537 (Cape Region). Ridgway, *Ibid.*, 537–539 (crit.; La Paz; Cape St. Lucas).

Ammodramus rostratus Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 299 (San José del Cabo; La Paz; Cape St. Lucas, and other localities).

Although the Large-billed Sparrow is not mentioned in Mr. Frazar's notes, he must have found it in considerable numbers, for his collection contains no less than fifty-five skins, of which four were obtained at La Paz in January and February, sixteen at Carmen Island in early March, and thirty-five at San José del Cabo at various dates between August 31 and November 9. All the specimens thus far collected in the Cape Region have been taken in autumn, winter, or early spring. Indeed, there is no present evidence that the bird breeds anywhere in Lower California. Mr. Bryant met with it only in February, 1888, when a few were found "among the bushes on the sand hills near Magdalena village," and Mr. Anthony does not seem to have seen it at all. According to Dr. Cooper, it is found abundantly at all seasons at San Diego and San Pedro, California. At the latter place he "saw them, in July, feeding their young."[2] Mr. Belding, referring to this statement, says, "I could not find the species about San Diego Bay or False Bay in April and May, 1881, nor in April and May of the years 1884 and 1885, in the latter year having followed the coast nearly fifty miles north of San Diego without finding it. I last saw it at San Diego, March 10, 1884. Its nesting places and nesting habits are still unknown."[3]

I have two specimens of *A. rostratus* taken at Guaymas on the western coast of Mexico.

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[1] Zoe, IV. 1893, 240.

[2] Baird, Brewer, and Ridgway, Hist. N. Amer. Birds, I. 1874, 543.

[3] Occ. Papers Calif. Acad. Sci., II., Land Birds Pacif. District, 1890, 145, 146.

Ammodramus rostratus guttatus (Lawr.).

St. Lucas Sparrow.

Passerculus guttatus Lawrence, Ann. Lyc. Nat. Hist. N. Y., VIII. 1867, 473 (orig. descr.; type from San José). Cooper, Orn. Cal., 1870, 185 (descr.; crit.; figures head; San José). Baird, Brewer, and Ridgway, Hist. N. Amer. Birds, I. 1874, pl. 25, fig. 1. Ridgway, Nom. N. Amer. Birds (Bull. U. S. Nat. Mus., no. 21), 1881, 23, 63, 74, no. 195; Proc. U. S. Nat. Mus., III. 1880, 2 (crit.); VI. 1883, 158, footnote ("doubtful"; crit.; S. Lower Calif.). Coues, Check List, 2d ed., 1882, 52, no. 231.

[*Zonotrichia*] *guttata* Gray, Hand-list, II. 1870, 95, no. 7,413.

[*Passerculus*] *guttatus* Coues, Key N. Amer. Birds, 1872, 136 (descr.; San José).

Passerculus rostratus, var. *guttatus* Coues, Check List, 1873, 33, no. 160 a. Baird, Brewer, and Ridgway, Hist. N. Amer. Birds, I. 1874, 544, pl. 25, fig. 1 (crit.; Cape St. Lucas). Jasper, Birds N. Amer., 1878, 154, pl. 104, fig. 14 (San José).

P.[*asserculus*] *guttatus* Ridgway, Proc. U. S. Nat. Mus., V. 1883, 537–539 (crit.; San José del Cabo). Salvin and Godman, Biol. Centr.-Amer., Aves, I. 1886, 382 (crit.). Coues, Key N. Amer. Birds, 4th ed., 1894, 364 (descr.; Cape St. Lucas).

Ammodramus rostratus guttatus Ridgway, Proc. U. S. Nat. Mus., VIII. 1885, 355. A. O. U., Check List, 1886, 267, no. 544 a. Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 299 (measurements of type; San José del Cabo; Santa Margarita Island).

Passerculus rostratus Sharpe, Cat. Birds Brit. Mus., XII. 1888, 680, 681, part (Cape St. Lucas).

A.[*mmodramus*] *rostratus guttatus* Ridgway, Man. N. Amer. Birds, 2d ed, 1896, 410 (descr.; vicinity of Cape St. Lucas).

Ammodramus halophilus McGregor, Auk, XV. 1898, 265–267 (orig. descr.; type from Abreojos Point; descr. nest and eggs).

Passerculus rostratus halophilus Ridgway, Birds N. and Midd. Amer., pt. I. 1901, 202 (descr.; Abreojos Point).

[*Passerculus*] *rostratus* Dubois, Synop. Avium, fasc. IX. 1901, 631, part.

Passerculus rostratus guttatus Ridgway, Birds N. and Midd. Amer., pt. I. 1901, 201, 202 (descr.; San José del Cabo).

Under the name *Ammodramus halophilus* Mr. R. C. McGregor has characterized a bird which he found breeding at Abreojos Point, Lower California, as "most closely related to *A. rostratus guttatus*, but 'uniformly larger and much darker; upper parts decidedly olivaceous instead of olive grayish.'" The included quotation was taken by Mr. McGregor from a letter written by Mr. Ridgway, who has since adopted the form as a subspecies in his Birds of North and Middle America, while it has been similarly recognized in the Tenth Supplement to the A. O. U. Check List.

It does not seem to me justifiable, however, to regard *halophilus* as distinct from *guttatus* until we have learned where the latter breeds, and especially what it is like *when in nuptial plumage.* It is at present represented by only three or four specimens, all of which were taken in autumn or winter, while all the examples of *halophilus* that have been thus far examined are adults in breeding condition. On comparing nine specimens of the latter from Abreojos Point (in the National Museum Collection) with the type of *guttatus*, and with two closely similar birds taken at the same locality (San José del Cabo) by Mr. Frazar, I fail to verify the differences in respect to size which are claimed to exist between the two forms. Indeed, two of the examples of *halophilus* have the wing of almost exactly the same length as that of the type of *guttatus*, while several of the former agree perfectly with the latter in respect to the size and shape of the bill. The color differences are obvious enough, but they are not greater than, nor dissimilar to, those which distinguish autumnal young of many of our Sparrows from adults of the same species killed at the height of the breeding season. In short, while it is not wholly impossible that *halophilus* may eventually prove to be a distinct race, the present indications are that this name has been based merely on fully mature, breeding specimens of *guttatus*, and that the type of the latter, with the few known birds which resemble it closely, are merely exceptionally small, slender-billed young in their first winter plumage.

The type specimen was taken by Mr. Xantus in December, 1859, at San José del Cabo, where Mr. Frazar obtained two similar examples in 1887, — one on October 3, the other on November 9. So far as we know, the bird is a winter visitor only to the Cape Region, and it evidently does not occur there in anything like so large numbers as *A. rostratus* or even *A. r. sanctorum.* Mr. Bryant "secured a single male on Santa Margarita Island, January 21, 1888, which Mr. Ridgway says is most like the type specimen of any he has seen."

In April and June, 1897, Mr. R. C. McGregor found what, as I have already stated, I consider to be the St. Lucas Sparrow breeding at Abreojos Point, Lower California, "in a salt marsh about five miles long by half a mile wide . . . surrounded by ocean on one side and hot desert on the others," and intersected by tidal creeks "which empty into a salt lake or pond lagoon." During his first visit, on April 19, the birds were abundant, and most of them were still "in perfect spring plumage." One of the females was flushed from her nest, which was placed "sixteen inches from the ground, in a tall bunch of glasswort, the top of which was bent over and in to form a covering," beneath which the bird could enter "from one side only." This nest was "larger than that of [the] San Benito Island species, made of salt grass and lined with fine shreds of grass and a few feathers of Larus." The three eggs, which it contained, were bluish white, with blotches of raw umber and spots of lilac. They measured respectively : .79 × .58, .80 × .58, and .78 × 58.

On June 17, the occasion of Mr. McGregor's second visit to Abreojos Point, the St. Lucas Sparrows were apparently laying their second clutches, for although no nests were found, "eggs on which the shell was formed" were taken from the oviducts of several of the females.

Ammodramus rostratus sanctorum (Ridgw.).

San Benito Sparrow.

Passerculus sanctorum Ridgway, Proc. U. S. Nat. Mus., V. 1883, 538 (San Benito I.).
P [*asserculus*] *sanctorum* Ridgway, *Loc. cit.*, 538, 539 (crit.).
Ammodramus (*Passerculus*) *sanctorum* Coues, Auk, XIV, 1897, 92, 93 (crit.).
Ammodramus sanctorum McGregor, Osprey, II. 1897, 42 (descr. habits, nest and eggs from San Benito Islands); Auk, XV. 1898, 264, 265 (descr. female, juvenal plumage).

Among the Passerculi collected by Mr. Frazar in or near the Cape Region are six specimens which, although variously intermediate in size between *A. rostratus* and *A. r. guttatus*, are colored more nearly like the latter. On comparing them with eleven examples (including the type) of *A. r. sanctorum* from the San Benito Islands, which Mr. Ridgway has been kind enough to send me for examination, I find that five belong, without question, to that recently separated — or rather resuscitated — insular race. The sixth bird is smaller than any of the others, and, indeed, not larger than one or two of the largest representatives of *halophilus* from Point Abreojos, but in respect to coloring it appears to agree more closely with *sanctorum*, to which, not without hesitation, I have finally decided to refer it.

This subspecies, originally named by the late Dr. Coues upwards of twenty-five years ago, but not until some time afterwards formally recognized either by him or by other ornithologists, is represented, as I have just said, by several skins in Mr. Frazar's collection, obtained at Carmen Island on March 6, and at San José del Cabo between October 10 and November 9. Mr. Ridgway has also mentioned three specimens "resembling '*P. sanctorum*' in coloration" which were collected by Mr. Belding at La Paz in January and February. From this we may infer that the bird is of regular and not very uncommon occurrence, in or near the Cape Region, in autumn, winter, and early spring. It is believed to be confined to Lower California at all seasons, and its only known breeding grounds are on the San Benito Islands. These islands, three in number, are described by Mr. R. C. McGregor as "situated about twenty miles west of Cerros Island. The two largest have each an area of several square miles and are from 200 to 400 feet high. The islands are quite dry during the summer season. For nine months almost no rain falls, while the porous and rocky character of the soil precludes the existence of springs or the formation of marshes and pools. The flora is semi-desert in nature. Several species of cacti and some small insular plants make up the vegetation, there being nothing which attains the size of a shrub or tree. Both the large islands are very hilly and these have been cut up by the heavy winter rains. The gullies so formed are often difficult or impossible to cross. It will thus be seen that the home of *Ammodramus sanctorum* is essentially different from that of any of the salt marsh *Ammodrami*."

Mr. McGregor further states that on these islands "the San Benito Sparrow far outnumbers all other land birds taken together." He examined three different nests, all of which were placed on the ground under small bushes. One found on March 30 contained three eggs. It "was sunken level with the ground, which served to support the thin walls. The outside is of large grass straws while the lining is of finer grass and a few feathers. The three eggs measure respectively .83 × .58, .82 × .61, .81 × .60. They were slightly incubated [when taken on April 1]. They are well marked all over with flecks and blotches of umber brown on a ground color of faint bluish white. One egg has one or two blackish hair lines on the large end."

Ammodramus savannarum bimaculatus (Swains.).

Western Grasshopper Sparrow.

Coturniculus passerinus perpallidus Belding, Proc. U. S. Nat. Mus., V. 1883, 540 (Cape Region).

Ammodramus savannarum perpallidus Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 300 (Cape Region).

The birds collected by Mr. Frazar have rather stout bills for *bimaculatus*, but they are typical of that form in respect to coloring and to the relative lengths of their wings and tails.

Mr. Belding gives this sparrow as "rare," but states that he saw it in several localities. Mr. Frazar took only four specimens, two at San José del Cabo on October 21 and 27, respectively, and two at Triunfo on December 5 and 15. No one else has reported the bird from the Cape Region, nor does it seem to have been detected elsewhere on the Peninsula. It has occurred at various places in California, and in the summer of 1875 was found by Mr. Henshaw breeding at Santa Barbara directly on the coast. Most of the birds which visit Mexico and Central America in winter are said to be *passerinus*, but Salvin and Godman mention[1] a Mexican specimen which is "as pale as another, marked by Mr. Ridgway himself as *C. perpallidus*."

Chondestes grammacus strigatus (Swains.).

Western Lark Sparrow.

Chondestes grammaca (not *Fringilla grammaca* Say) Baird, Proc. Acad. Nat. Sci. Phila., 1859, 301, 304 (Cape St. Lucas).

Chondestes grammica strigata Belding, Proc. U. S. Nat. Mus., V. 1883, 540 (Cape Region).

Chondestes grammacus strigatus Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 300 (Cape Region). Townsend, Proc. U. S. Nat. Mus., XIII. 1890, 137 (Cape St. Lucas).

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[1] Biol. Centr.-Amer., Aves, I. 1886, 385.

The Western Lark Sparrow is a common winter resident of the Cape Region, arriving from the North early in October (Mr. Frazar's first specimen was taken on the 8th). It is apparently not restricted to any particular kind of country, for Mr. Frazar found it quite as numerous in the flat sea-coast region about San José del Cabo as among the hills at Pierce's Ranch and Triunfo. None were seen by him, however, on the Sierra de la Laguna.

To the northward of the Cape Region, the Western Lark Sparrow is "generally distributed over the peninsula in winter and spring," according to Mr. Bryant. It will be strange if it is not found breeding in the more northern districts, for it nests commonly in southern California, and thence northward to British Columbia. Its winter range includes most of Mexico and extends to Guatemala.

Zonotrichia leucophrys (Forst.).

WHITE-CROWNED SPARROW.

Zonotrichia leucophrys BAIRD, Proc. Acad. Nat. Sci. Phila., 1859, 301 (Cape St. Lucas), 304 (crit.; Cape St. Lucas). BAIRD, BREWER, and RIDGWAY, Hist. N. Amer. Birds, I. 1874, 567 (Cape St. Lucas in winter). BELDING, Proc. U. S. Nat. Mus., V. 1883, 540 (La Paz and s.). RIDGWAY, *Ibid.*, footnote, (Cape Region). BRYANT, Proc. Calif. Acad. Sci., 2d ser., II., 1889, 300 (Cape Region).

This is another very common winter resident. Mr. Frazar found it most numerous at San José del Cabo, where his first autumnal specimen, an adult male, was obtained on October 11. About a week before this, a White-crowned Sparrow was heard singing, but it was not shot and may have been *gambelii*. Mr. Belding has taken *leucophrys* on Cerros Island in May, and Mr. Bryant "found it on Santa Margarita Island and various places on the peninsula."

The White-crowned Sparrow breeds in the Sierra's of California, "in the subalpine meadows from Alpine County to the northern part of Butte County."[1] It migrates at least as far as southward as Alamos, western Mexico, whence I have typical specimens. In the interior it has been reported from Tamaulipas, Guanajuato, and the valley of Mexico.

Mr. Anthony states that "all of the white crowns [*i. e.*, *leucophrys*, *gambelii*, and *nuttalli*] are abundant about the base of San Pedro [Martir] during the winter months, and a few are to be seen in the pines during migrations. But few specimens were taken and the comparative abundance of the different species was not determined."[2]

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[1] Belding, Occ. Papers Calif. Acad. Sci., II., Land Birds Pacif. District, 1890, 148.

[2] Zoe, IV. 1893, 241.

Zonotrichia leucophrys gambelii (NUTT.).

INTERMEDIATE SPARROW.

Zonotrichia gambeli intermedia RIDGWAY, Proc. U. S. Nat. Mus., V. 1883, 533, footnote (San José del Cabo; San Nicholas).

Z.[onotrichia] intermedia RIDGWAY, *Loc. cit.*, 540, footnote (Cape St. Lucas).

Zonotrichia intermedia BRYANT, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 300 (Cape St. Lucas).

The Intermediate Sparrow was obtained by Xantus at San José del Cabo on November 15, and at San Nicolas in October. Mr. Belding did not meet with it, and Mr. Frazar took only four specimens, one at Triunfo on April 18, and three at San José del Cabo, on October 13, and November 3 and 5, respectively. From this it appears that in the Cape Region *gambelii* is much less numerous than *leucophrys*, if not of positively rare occurrence. To the northward it was not seen by Mr. Bryant, but Mr. Anthony found it in the northwestern part of the Peninsula. Typical *nuttalli* has occurred on San Pedro Martir, about Ensenada, and on Santa Margarita Island, but not as yet in the Cape Region.

Z. l. gambelii is an abundant winter resident in most parts of California, but it is not known to breed south of Oregon, while its summer range extends into Alaska. Mr. Frazar collected numerous specimens near the city of Chihuahua, Mexico, in the autumn of 1888, but he found none south of Guaymas on the west coast. These facts suggest that *gambelii*, at all seasons, has a more northern distribution on the Pacific slope than its near ally *leucophrys*.

Spizella socialis arizonae COUES.

WESTERN CHIPPING SPARROW.

Spizella socialis arizonae BELDING, Proc. U. S. Nat. Mus., VI. 1883, 347 (Victoria Mts.). BRYANT, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 300 (Victoria Mts.).

Mr. Belding characterizes this sparrow as "rather rare," and says that he did not see it below 3000 feet altitude, both of which statements are confirmed by the experience of Mr. Frazar, who obtained only a single specimen, — a male, killed on April 30, on the summit of the Sierra de la Laguna. Mr. Bryant did not meet with the bird at all, but Mr. Anthony has found it "at lat. 31° N., from the coast to 2,500 feet altitude" (Bryant) and about the base of San Pedro Martir, where it is abundant and resident.[1] It is rather common in summer in most parts of California, and ranges northward to the Yukon

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[1] Anthony, Zoe, IV. 1893, 241.

Valley, Alaska. In the Sierra Madre Mountains of Mexico it breeds as far south as Pinos Altos, whence I have typical specimens, taken in June. None of my collectors have found it on the west coast of Mexico.

Spizella pallida (Swains.).

Clay-colored Sparrow.

Spizella pallida **Belding**, Proc. U. S. Nat. Mus., V. 1883, 540 (San José and elsewhere in Cape Region). **Bryant**, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 301 (Cape Region).

This is a common winter resident in the Cape Region, whence it was first reported by Mr. Belding. Mr. Frazar found it numerous at San José del Cabo (where his first specimen was shot on October 14) and at Triunfo (in December). He also took it at Santiago, but it is not included in his lists of birds seen at La Paz and on the Sierra de la Laguna. Mr. Bryant notes it as common on Santa Margarita Island and northward on the Peninsula, presumably in autumn, winter, or spring, for there is no reason to suppose that it breeds as far south as even the northern part of Lower California.

Dr. Cooper has recorded *S. pallida* as "common in April" at Fort Mojave,[1] but no one else seems to have found it in California. It breeds in the interior of North America and migrates as far southward as Oaxaca in southern Mexico.

Spizella breweri Cass.

Brewer's Sparrow.

Spizella breweri **Belding**, Proc. U. S. Nat. Mus., V. 1883, 540 (Cape Region). **Bryant**, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 301 (Cape Region).

Mr. Belding considers Brewer's Sparrow "abundant," but Mr. Frazar did not find it at all common, and his collection contains only five specimens as against thirty-nine of *pallida*. He saw it at La Paz, Triunfo, and San José del Cabo, as well as on Carmen Island. Mr. Bryant mentions only one example, which he shot "at San Julio (near Comondu)," and which he considers "intermediate between this species and *S. pallida*." *S. breweri* is, of course, only a winter visitor to the Cape Region. Mr. Frazar's latest spring date is April 20.

North of San Diego, in California, Brewer's Sparrow is seldom seen near the coast, but east of the Sierras it is of regular and frequent occurrence at its seasons of migration. Mr. Grinnell states that it is "tolerably common in summer from 5,000 to 7,000 feet on the brushy mountain sides between Pine

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[1] Proc. Calif. Acad. Sci., II. 1863, 122.

Flats and Mt. Waterman," where full-grown young were obtained on July 3, 1897,[1] and Mr. Belding has found it "July 1 on Castle Peak, Nevada County, up to 8,000 feet," where it doubtless breeds.[2] In Mexico it occurs plentifully in winter and early spring near the city of Chihuahua, and it has been taken still further south, in Durango. I have specimens shot at Oposura, Sonora, but none from the west coast south of Guaymas.

Spizella atrogularis (CAB.).

BLACK-CHINNED SPARROW.

Spizella atrigularis BAIRD, BREWER, and RIDGWAY, Hist. N. Amer. Birds, I. 1874, pl. 26, fig. 12; II. 1874, 15 (Cape St. Lucas). BELDING, Proc. U. S. Nat. Mus., VI. 1883, 348 (Victoria Mts.; Pescadero). BRYANT, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 301 (Cape Region).

The specimens taken in Lower California by Mr. Frazar appear to be peculiar only in respect to their bills, which are somewhat broader than in the birds which breed in southern California.

The Black-chinned Sparrow is apparently of rather uncommon occurrence in the Cape Region, where it was first detected by Mr. Belding, who, in the winter of 1882–83, saw a single bird in the mountains, and afterwards, near Pescadero, a small flock, from which a single specimen was obtained. Mr. Frazar took two at La Paz in February, and six at Triunfo in April, the latest on the 23d of the month. To the northward, according to Mr. Bryant, it was found by Mr. Belding in May, 1885, between San Rafael and San Pedro Martir, but nowhere numerously, and by Mr. Anthony on San Pedro Martir[3] and at Valladeres. At the place last named "they were common and nesting" (Bryant). It is not impossible that a few pairs breed in the Cape Region, also, but this remains to be proved.

This Sparrow has been found in summer at a number of localities in southern California, where, according to Mr. F. Stephens, it nests in chemisal brush on steep hillsides at between 1,000 and 3,000 feet altitude. It has occurred as far to the northward as Inyo county in the interior of the State and in Alameda county near the coast. It is said to have a wide range in Mexico, but a single bird shot by Mr. J. C. Cahoon at Oposura, Sonora on May 10, 1887, is the only specimen which my collectors have obtained in that country.

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[1] Pub. II. Pasadena Acad. Sci., 1898, 37.

[2] Occ. Papers Calif. Acad. Sci., II., Land Birds Pacif. District, 1890, 157.

[3] Mr. Anthony has since reported that near San Pedro Martir the species is "rather common in the hills from the coast to the base of the mountain," and that he is "sure that its song was heard in May, 1887, at 10,000 feet elevation." Zoe, IV. 1893, 241.

Junco bairdi Ridgw.

Baird's Junco.

Junco bairdi (Belding MS.) Ridgway, Proc. U. S. Nat. Mus., VI. 1883, 155, 156 (orig. descr.; types from Laguna), 158, footnote (crit.; S. Lower Calif.), 348 (measurements of birds from Laguna and Victoria Mts.); Birds N. and Midd. Amer., pt. I. 1901, 294, 295 (descr.; Victoria Mts.; Mount Miraflores, etc.). Belding, Proc. U. S. Nat. Mus., VI. 1883, 346, 348 (Victoria Mts.). A. O. U., Check List, 1886, 276, no. 571. Sharpe, Cat. Birds Brit. Mus., XII. 1888, 653 (descr.; Lower Calif.). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 301 (Victoria Mts.; La Laguna); Zoe, II. 1891, 198 (Victoria Mts.).

Junco hiemalis bairdi Coues, Key N. Amer. Birds, 4th ed., 1894, 875 (descr.; Lower Calif.).

J.[unco] bairdi Ridgway, Man. N. Amer. Birds, 2d ed., 1896, 425 (descr.; mts. of S. Lower Calif.).

[*Junco insularis*] var. *bairdi* Dubois, Synop. Avium, fasc. IX. 1901, 629 (Basse-Californie).

The female is uniformly smaller than the male, and her general coloring, particularly the ash of the head and the cinnamon buff of the sides, is duller and paler. The rufous brown of the back is also much lighter than in the male, being scarcely deeper than the color on the sides. The lores are dusky instead of blackish.

Winter plumage: — My series contains only three specimens in winter plumage. Of these, a male, taken on November 28, is considerably deeper and richer colored than are any of the spring birds, and the rufous brown of the neck is more strongly tinged with olive, while the crissum and under tail coverts are distinctly buffy. The cinnamon of the sides, however, is duller than in spring. The other two specimens are females. They differ from the male just described only in having the ash of the throat much lighter, the buff of the crissum and under tail coverts deeper, the brown of the back brighter and more rufous. They are very much richer colored than any of the spring females.

Individual variations: — The brown of the upper parts varies from faded cinnamon brown to deep cinnamon rufous — almost chestnut brown in some specimens; the color of the sides from dull pale cinnamon to light cinnamon rufous. There is a tendency to olivaceous tipping on the feathers of the occiput and nape as well as, sometimes, on those of the crown and forehead. A specimen taken on May 24 has a narrow but well-defined slaty black collar extending from the sides of the neck across the forward part of the back or the lower part of the nape. Two other birds, killed at about the same time, also show traces of this collar. In all three the slaty black is confined to the extreme tips of the feathers. Some of the duller males are distinguishable from the brightest females only by the clearer tone of the ash on the top and sides of the head.

This species was discovered by Mr. Belding in 1883, in the mountains south of La Paz where it "was very common . . . above 3,000 feet altitude." Mr. Frazar found it in considerable numbers on the Sierra de la Laguna in May and early June, but so few were observed here in December as to lead him to conclude that many individuals must descend to lower levels to pass the winter. They cannot, however, go very far down, for none were met with at San José del Rancho, and but one (on April 13) at Triunfo. On the Sierras they inhabit the pine and oak woods, and, like most Juncos, are tame and familiar. They often came into a shed where Mr. Frazar prepared his specimens, and hopped about his feet, under the table, or pecked at the dried venison suspended from the roof. No nests were found, but late in May a bird was seen collecting building material.

Baird's Junco appears to be confined to the extreme southern end of the Peninsula, never having been observed so far north, even, as La Paz. It is, therefore, one of the most characteristic birds of the Cape fauna.

Amphispiza bilineata deserticola Ridgw.

DESERT SPARROW.

Amphispiza bilineata (not *Emberiza bilineata* Cassin) Belding, Proc. U. S. Nat. Mus., V. 1883, 540 (Cape Region). Salvin and Godman, Biol. Centr.-Amer., Aves, I. 1886, 367, 368, part (descr. female from La Paz). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 302 (Cape Region).

Mr. Frazar found the Desert Sparrow at Triunfo, San José del Cabo, La Paz, and Carmen Island. It was commonest at La Paz, and least numerous at San José del Cabo. Neither his notes nor the dates at which his specimens were collected afford any evidence that it breeds in the Cape Region, but Mr. Bryant has found nests on Santa Margarita and Magdalena Islands where it was "the most common and generally distributed species." It appears to range over the entire Peninsula, but in California is practically confined to the region east of the Sierras. I have winter specimens taken at Guaymas, Cumpas, and Bacuachi in western Mexico and a large series collected near the city of Chihuahua in autumn. These Mexican specimens do not differ, so far as I can discover, from those which Mr. Frazar obtained in Lower California, although the Guaymas bird should represent Mr. Nelson's *A. b. pacifica*,[1] the type locality of which is Alamos, Sonora.

Aimophila ruficeps sororia Ridgw.

LAGUNA SPARROW.

Peucaea ruficeps Cooper, Orn. Cal., 1870, 218, part. Coues, Check List, 1873, 35, no. 171, part; 2d ed., 1882, 55, no. 255, part. Ridgway, Nom. N. Amer.

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[1] Auk, XVII. 1900, 267.

Birds (Bull. U. S. Nat. Mus., no. 21) 1881, 25, no. 230, part. A. O. U., Check List, 1886, 278, no. 580, part.

Peucaea ruficeps boucardi (not *Zonotrichia boucardi* SCLATER) BELDING, Proc. U. S. Nat. Mus., VI. 1883, 348 (Victoria Mts.). BRYANT, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 302 (Victoria Mts.; ? Llanos de San Julian).

P.[*eucaea*] *ruficeps* COUES, Key N. Amer. Birds, 4th ed., 1894, 374, 375, part.

P.[*eucaea*] *ruficeps boucardi* RIDGWAY, Man. N. Amer. Birds, 2d ed., 1896, 429, part (Lower Calif.).

Aimophila ruficeps sororia RIDGWAY, Auk, XV. 1898, 226, 227 (orig. descr.; type from Victoria Mts.); Birds N. and Midd. Amer. pt. I. 1901, 248 (descr.; Laguna; Victoria Mts.). A. O. U. COMM., Auk, XVI. 1899, 120, no. 580 c.

[*Haemophila ruficeps*] var. *sororia* DUBOIS, Synop. Avium, fasc. IX. 1901, 635 (Basse-Californie S.).

It is probable that Mr. Bryant's record of the occurrence of *Peucaea ruficeps boucardi* at Llanos de San Julian (about latitude 29° N.) relates to the present form, but this cannot be considered assured until the specimen taken (on April 19, 1889) at the locality just named has been carefully re-examined. Mr. Anthony states that *Aimophila ruficeps* "seems to be rather common in a few favored localities along the base of San Pedro" Martir and that "a series of four skins taken between Tia Juana and the base of San Pedro are practically indistinguishable from Southern California examples."[1]

The specimens collected by Mr. Frazar at Triunfo sustain very satisfactorily the characters ascribed by Mr. Ridgway to *sororia*. In respect to color and markings, this form is about intermediate between *ruficeps* and *scottii*, but its bill is unlike that of either of these races. It seems to be a perfectly good subspecies.

It was discovered in the Cape Region by Mr. Belding, who found it "common on grassy hillsides above 2,500 feet altitude," and paired in February. Mr. Frazar met with it only at Triunfo, where it was not common in April, and still less numerous in June, the majority probably going further north to spend the summer. A few remained to breed, however, for a female taken on June 23 had evidently laid all her eggs, and was incubating.

The Laguna Sparrow is believed to be confined to the more southern portions of the Peninsula, but the northern limits of its range are not as yet definitely known.

Melospiza lincolnii (AUD.).

LINCOLN'S SPARROW.

Melospiza lincolni BELDING, Proc. U. S. Nat. Mus., VI. 1883, 348, part (Victoria Mts.), 350 (La Paz and s.). BRYANT, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 303, part (Cape Region).

Mr. Belding found this species less common than the Laguna Sparrow in the mountains, and rare in the low country near the coast. Mr. Frazar met with it only at Santiago, where, on November 21, two specimens were shot and a third seen in tules on the border of the lagoon. To the northward, Mr. Bryant has noted it at Comondu and Jesus Maria, and Mr. Anthony has observed it "on the northwest coast during migration" (Bryant). It probably does not breed on the Peninsula, for in California, where it is rather common in spring and autumn, and not uncommon locally in winter, it has been found in summer only among the mountains from 4,000 feet altitude upwards. It migrates as far south as Guatemala, and is common in winter in western Mexico.

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[1] Zoe, IV. 1893, 242.

Melospiza lincolnii striata Brewst.

Forbush's Sparrow.

Melospiza lincolni (not *Fringilla lincolnii* Audubon) Belding, Proc. U. S. Nat Mus., VI. 1883, 348, part (Victoria Mts.). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 303, part (Cape Region).

Mr. Chapman has expressed some doubts[1] as to the validity of *striata*, to which he refers two autumn birds taken in British Columbia by Mr. Streator, and Mr. Ridgway, in his Birds of North and Middle America, cites the name, preceded by a question-mark, in his synonymy of *M. lincolnii*. I see no reason why the existence of intermediate specimens, such as those to which Mr. Chapman calls attention, should be necessarily prejudicial to the recognition of the form as a subspecies, although its standing cannot perhaps be regarded as assured until its breeding-grounds are definitely known, and fully mature birds in summer plumage have been examined.

A specimen in the United States National Museum, taken by Mr. Belding in the Victoria Mountains on February 20, 1883, seems to be referable to this subspecies, whose summer home probably lies to the northward of the United States on or near the Pacific coast, — perhaps in British Columbia, where the type specimens were obtained.

Pipilo maculatus magnirostris Brewst.

Mountain Towhee.

Pipilo maculatus megalonyx (not *Pipilo megalonyx* Baird) Belding, Proc. U. S. Nat. Mus., V. 1883, 549 (Miraflores); VI. 1883, 348 (Victoria Mts.). A. O. U., Check List, 1886, 284, no. 588 a, part. Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 303 (San José del Cabo).

Pipilo megalonyx Salvin and Godman, Biol. Centr.-Amer., Aves, I. 1886, 409, part (Lower Calif.).

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[1] Bull. Amer. Mus. Nat. Hist., III. 1891, 148.

Pipilo maculatus magnirostris BREWSTER, Auk, VIII. 1891, 146, 147 (orig. descr.; types from Sierra de la Laguna). BRYANT, Zoe, II. 1891, 198 (Victoria Mts.). RIDGWAY, Birds N. and Midd. Amer., pt. I. 1901, 414, 415 (descr.; mt. districts of S. Lower Calif.).

[*Pipilo maculatus*] var. *magnirostris* DUBOIS, Synop. Avium, fasc. IX. 1901, 637 (Basse-Californie).

Concerning the characters by which *P. m. magnirostris* may be distinguished from its nearest allies, I have nothing to add to what appeared in my original description of the former.

This Towhee which, until recently, has been confounded with *P. m. megalonyx*, is probably confined to the Cape Region, where it is resident, and very common locally in the mountains south of La Paz. Mr. Frazar found it in the greatest numbers on the Sierra de la Laguna in May and early June. A few were also seen on the summit of this mountain in December, but most of those which pass the summer there evidently descend to lower levels at the approach of winter. They were rare at Triunfo in summer, but very numerous at all seasons about San José del Rancho, where a nest containing three eggs was taken on July 22. According to Mr. Bryant, no Towhees of the *P. maculatus* group have been detected in Lower California north of La Paz excepting "in the region of San Pedro Martir," where Mr. Anthony has found *P. m. megalonyx* breeding at from 2,500 to 11,000 feet altitude. I have not seen specimens from this region, but they are not likely to belong to the present subspecies.

The nest found at San José del Rancho was placed "on the ground under a bush close to roots." It measures externally 3.55 in diameter by 1.75 in depth; internally 2.15 in diameter by 1.50 in depth. It is composed of weed stalks and coarse grass, and is lined with fine grass and a little horsehair. The eggs are elliptical-ovate in shape, and measure respectively 1.02 × .71; 1.00 × .75; and 1.02 × .73. Their ground color is dull white, but this is nearly concealed by innumerable fine spots of lavender and pinkish brown, the latter color being most prevalent and conspicuous about the larger ends. These eggs are very closely matched by several eggs of *P. erythrophthalmus* in my collection.

Pipilo fuscus albigula (BAIRD).

ST. LUCAS TOWHEE.

Pipilo albigula BAIRD, Proc. Acad. Nat. Sci. Phila., 1859, 301 (Cape St. Lucas), 305 (orig. descr.; types from Cape St. Lucas). ELLIOT, Illustr. New and Unfig. N. Amer. Birds, I. 1869, pl. 15 (descr.). COOPER, Orn. Cal., 1870, 248 (descr.; figures head; Cape St. Lucas). BAIRD, BREWER, and RIDGWAY, Hist. N. Amer. Birds, II. 1874, pl. 31, fig. 11. SHARPE, Cat. Birds Brit. Mus., XII. 1888, 755 (descr.; Cape St. Lucas; La Paz). RIDGWAY, Birds N. and Midd. Amer., pt. I. 1901, 433, 434 (descr.; Cape St. Lucas district).

[*Pipilo*] *albigula* GRAY, Hand-list, II. 1870, 92, no. 7,362.

[*Pipilo fuscus*] var. *albigula* Coues, Key N. Amer. Birds, 1872, 152 (descr.; Cape St. Lucas). Dubois, Synop. Avium, fasc. IX. 1901, 637 (Basse-Californie).

Pipilo fuscus, var. *albigula* Coues, Check List, 1873, 43, no. 206 a. Baird, Brewer, and Ridgway, Hist. N. Amer. Birds, II. 1874, 127, 128, pl. 31, fig. 11 (descr. bird and eggs from Cape St. Lucas; crit.). Jasper, Birds N. Amer., 1878, 156, pl. 104, fig. 32 (S. Lower Calif.).

Pipilo fuscus albigula Ridgway, Nom. N. Amer. Birds (Bull. U. S. Nat. Mus. no. 21), 1881, 26, 64, 74, no. 240 a; Proc. U. S. Nat. Mus., V. 1883, 540 (crit.); VI. 1883, 158, footnote (crit.; S. Lower Calif.). Coues, Check List, 2d ed., 1882, 61, no. 307. Belding, Proc. U. S. Nat. Mus., V. 1883, 540 (Cape Region); VI. 1883, 345 (Cape Region). A. O. U., Check List, 1886, 285, no. 591 a. Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 304 (Cape St. Lucas). Townsend, Proc. U. S. Nat. Mus., XIII. 1890, 137 (La Paz).

P.[*ipilo*] *fuscus albigula* Belding, Proc. U. S. Nat. Mus., VI. 1883, 344 (Lower Calif.). Ridgway, Man. N. Amer. Birds, 2d ed., 1896, 440 (descr.; Lower Calif.).

P.[*ipilo*] *f.*[*uscus*] *albigula* Coues, Key N. Amer. Birds, 4th ed., 1894, 397 (descr.; Lower Calif.).

Young in juvenal plumage: — Female (No. 15,973, San José del Cabo, October 31, 1887). Above, including the crown, uniform pale wood brown, the greater and middle wing coverts clayey buff; wings and tail light clove brown, the quills edged with ochraceous, the tail feathers tipped with the same, forming obscure terminal spots; middle of the breast and fore part of the abdomen brownish white; sides of the breast dull olive gray; remainder of the under parts rusty ochraceous, deepest on the under tail coverts, crissum, and flanks; buffy of throat bordered on each side by a dusky malar stripe which, above, is separated from a still more obscure rictal stripe by a narrow interval of buffy; sides of the head uniform with the back; lores, however, distinctly buffy; a few obscure, dusky spots on the breast.

In the specimen just described the feathers of the jugulum and breast seem to be largely those of the first winter plumage. There are also a few feathers of this plumage among the interscapulars, but otherwise the bird, although taken so late in the season, is unmistakably in juvenal plumage.

Another female (Triunfo, December 5, 1887), apparently a young bird in winter plumage, has the spots on the jugulum as well defined as in many of the spring specimens. The breast and a portion of the abdomen are also finely spotted with dark brown, a feature which I do not find in any other example in the entire series. This spotting is probably a characteristic of the juvenal plumage which, in this individual, has reappeared in the first winter plumage. It will be remembered in this connection that young in first plumage of the allied forms *P. f. mesoleucus* and *P. fuscus* are rather thickly and generally spotted over most of the under parts. The absence of these markings in No. 15,973 is due, no doubt, as above suggested, to the fact that the feathers of the breast had been already changed for those of the first winter plumage.

Most of the autumnal birds in the series before me have the greater and middle wing coverts tipped with ochraceous. In some of them the color of the crown is but slightly more rufescent than that of the back. In others it is nearly as much so as in spring. As a rule, the coloring of the upper parts is clearer and more olivaceous in autumnal than in spring specimens.

Individual variations: — The most marked individual variation is in respect to the number and size of the black spots on the jugulum. These are sometimes numerous, large, and conspicuous, sometimes almost wholly wanting. As a rule, they form a fairly well-defined border about the buffy space which they enclose. Several birds have the throat as well as the jugulum spotted finely but thickly over its entire extent. As Mr. Ridgway has remarked, the buffy of the throat is not always palest posteriorly, being sometimes uniform throughout. Most of my specimens have the outer tail feathers narrowly tipped with rusty, but in a few these feathers are perfectly plain. The rufescent color of the crown is a constant character in spring birds.

The collection contains a partial albino (No. 16,977) taken at San José del Rancho on July 6.

This Towhee, which was discovered at Cape St. Lucas by Mr. Xantus, is confined to Lower California. In the Cape Region it was "not often seen at any locality" by Mr. Belding during his visit of 1881–82, and it receives no mention whatever in the paper relating to his explorations of the following year. Mr. Frazar, however, collected over *one hundred specimens*, and notes the bird as "common about La Paz up to the middle of March, after which it entirely disappeared; exceedingly abundant at Triunfo in April, but only common in June, and less numerous still in December; rare on the top of the Sierra de la Laguna in May and early June; and not common at San José del Rancho in December." At San José del Cabo a specimen taken on October 29 was the only one seen. These facts indicate that the birds move about a good deal at different seasons, and that many which winter in the Cape Region breed further to the northward.

Mr. Bryant says that he has found *albigula* "as far north as lat. 30°." Since this statement was published, however, Mr. Anthony has described *P. f. senicula* which, he states, is intermediate in coloring, as well as in distribution, between *crissalis* and *albigula*, and to which he apparently refers all the birds that he has seen from the upper parts of the Peninsula "as far south as 29° at least," adding "it is to be regretted that there are no specimens available from the country between San Fernando and Cape St. Lucas."[1] It should be noted in this connection that San Fernando is in about latitude 29° 30′ north,[2] and hence very near the point to which Mr. Bryant claims that the northern range of *albigula* extends. This evidence leaves us in doubt as to whether or not the forms *albigula* and *senicula* meet during the breeding season in the central portions of Lower California. We are also ignorant as to whether or not they intergrade. Mr. Ridgway treats *albigula* as a full species in his Birds of North and Middle America, but in view of the uncertainties just discussed, I prefer to include it here as a subspecies of *P. fuscus*.

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[1] Auk, XII. 1895, 109–112.

[2] Anthony, *Loc. cit.*, 134.

At San José del Rancho Mr. Frazar collected three nests of this Towhee, on July 20, 24, and 29 respectively. They are composed of dry grass and weed-stalks, one having also a few twigs on the outside. One is lined with black horsehair, another with mixed white and black horsehair, the third with horsehair and fine grass. All three are considerably smaller than a nest of *P. f. crissalis* in my collection. Two were built in bushes and one in a tree, the height varying from six to eight feet. Each nest contained three eggs. Those of the set taken on July 24 were slightly incubated, all the others freshly laid. The ground color of these eggs is greenish white with a tinge of bluish, very like that of eggs of the Red-winged Blackbird. They are marked, chiefly about the larger ends, with irregular spots, dashes, and pen-lines of lavender and purplish black. They average .97 × .68, with extremes of .99 × .70, .98 × .64, and .96 × .69. Dr. Brewer mentions[1] a nest found by Mr. Xantus in a "wild *Humulus* thicket," and another "in a thicket of wild roses in the garden fence." One of these nests contained four eggs.

Oreospiza chlorura (Aud.).

Green-tailed Towhee.

Pipilo chlorurus Belding, Proc. U. S. Nat. Mus., V. 1883, 540 (Cape Region); VI. 1883, 348 (Victoria Mts.). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 304 (Cape Region).

The Green-tailed Towhee is a rather common winter resident in the Cape Region, frequenting alike the open, arid country near the coast and the wooded cañons and slopes of the mountains, but evidently preferring the latter. Mr. Frazar found it most numerously at San José del Rancho and Triunfo. It was rare at La Paz in January, February, and March, but not uncommon at San José del Cabo after October 4, the date of its first appearance in autumn. A single specimen (a female), taken on the Sierra de la Laguna on May 25, was probably a belated straggler, for the next previous date was April 21, when one was seen at Triunfo. Mr. Bryant "obtained specimens on Santa Margarita Island and at various places on the peninsula," to the northward.

This Towhee is apparently nowhere common along the coast of California, where it occurs chiefly during migration, and where, near the southern boundary, a few are said to winter, also. It breeds on the higher mountains of Los Angeles county, California, and northward along the eastern slope of the Sierras nearly or quite to the Columbia River. In winter it is found in western Mexico, as far south as Sinaloa.

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[1] Baird, Brewer, and Ridgway, Hist. N. Amer. Birds, II. 1874, 128.

Cardinalis cardinalis igneus (BAIRD).

ST. LUCAS CARDINAL.

Cardinalis igneus BAIRD, Proc. Acad. Nat. Sci. Phila., 1859, 301 (Cape St. Lucas), 305 (orig. descr.; types from Cape St. Lucas). ELLIOT, Illustr. New and Unfig. N. Amer. Birds, I. 1869, pl. 16 (descr.). COOPER, Orn. Cal., 1870, 238, 239, part (Cape St. Lucas). BAIRD, BREWER, and RIDGWAY, Hist. N. Amer. Birds, II. 1874, pl. 30, fig. 10. SALVIN and GODMAN, Biol. Centr.-Amer., Aves, I. 1884, 341, part (crit.). BARTLETT, Mon. Ploc. and Fring., pt. III. 1889, 14–16, part (descr.; crit.; La Paz; San José). SHARPE, Cat. Birds Brit. Mus., XII. 1888, 164–166, part (San José; Cape St. Lucas; subsp. of *Cardinalis cardinalis*).

Cardinalis virginianus SCLATER, Cat. Amer. Birds, 1862, 100, part (Cape St. Lucas).

Cardinalis virginianus, var. *igneus* RIDGWAY, Amer. Journ. Sci., 3d ser., V. 1863, 39, part (remarks on color and geog. distr.; Cape St. Lucas). COUES, Check List, 1873, 41, no. 203 a, part. BAIRD, BREWER, and RIDGWAY, Hist. N. Amer. Birds, II. 1874, 103, part, pl. 30, fig. 10 (nesting habits at Cape St. Lucas). JASPER, Birds N. Amer., 1878, 155, pl. 104, fig. 22, part (Cape St. Lucas).

[*Cardinalis*] *igneus* GRAY, Hand-list, II. 1870, 102, no. 7,532, part.

[*Cardinalis virginianus*] var. *igneus* COUES, Key N. Amer. Birds, 1872, 151, part (descr.; Cape St. Lucas). RIDGWAY, Amer. Nat., VII. 1873, 618, part (Cape St. Lucas).

[*Cardinalis virginianus*] c. *igneus* COUES, Birds Northwest, 1874, 172, part (Cape St. Lucas).

Cardinalis virginianus igneus RIDGWAY, Nom. N. Amer. Birds (Bull. U. S. Nat. Mus., no. 21), 1881, 26, 64, no. 242 a, part; Proc. U. S. Nat. Mus., V. 1883, 541 (crit.). BELDING, *Ibid.* (Cape Region); VI. 1883, 345 (Cape Region).

Cardinalis virginiana ignea COUES, Check List, 2d ed., 1882, 60, no. 300, part.

Cardinalis cardinalis igneus STEJNEGER, Auk, I. 1884, 171. A. O. U., Check List, 1886, 286, no. 593 b. BRYANT, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 304 (Cape Region; Santa Margarita Island; Comondu); Zoe, II. 1891, 188 (San José del Cabo). RIDGWAY, Birds N. and Midd. Amer., pt. I. 1901, 647, 648 (descr.; Cape St. Lucas district).

Cardinalis ruber igneus STEJNEGER, Auk, I. 1884, 172, part.

C.[*ardinalis*] *v.* [*irginianus*] *igneus* COUES, Key N. Amer. Birds, 4th ed., 1894, 394, 395, part (Lower Calif.).

C.[*ardinalis*] *cardinalis igneus* RIDGWAY, Man. N. Amer. Birds, 2d ed., 1896, 442 (Lower Calif.).

[*Cardinalis ruber*] var. *ignea* DUBOIS, Synop. Avium, fasc. IX. 1901, 619 (Basse-Californie).

Individual variations: — *Males.* The red is exceedingly variable in tint, ranging from the deepest geranium red through vermilion to a pale rose salmon. The back varies from ashy brown to faded grayish brown, with always a more or less strong tinge of red. The absence of the black frontal band appears to be quite constant. There is much variation in the size and shape of the bill as well as in the length of the wings and tail, but the latter is nearly always shorter than in Arizona specimens of *superbus*. Many of my Sonora representatives of the latter are, however, positively indistinguishable from the larger examples of *igneus*.

Females. Several of my specimens have the entire top of the head as well as the cheeks, throat, and breast, strongly tinged with red; in others, these parts are perfectly plain, while the two styles are connected by a chain of variously intermediate birds. There is also much variation in respect to the amount of blackish on the chin, lores, etc. In a few examples this blackish is almost wholly wanting.

Winter plumage: — Adult males in autumn and early winter differ from spring males only in having the feathers of the back more broadly tipped with purer ashy; those of the crown with dull olive; those of the under parts with grayish white.

Young males in their first winter plumage have the back, nape, and sides of the neck uniform ashy, or brownish ashy, with, however, much concealed reddish; the top of the head and crest strongly washed with olivaceous; the under parts, except the throat and under tail coverts, much variegated with dull yellowish olive; the bill mottled with large patches of blackish. The tint of the red of the head and under parts varies quite as much in these young males as with spring adults, showing that it has no connection with age or season.

Young females in first winter plumage have the back, wing coverts, inner secondaries, and exposed outer surfaces of most of the remaining wing quills, as well as all the tail feathers, much ashier than in breeding birds; the top and sides of the head strongly ochraceous; the throat, lores, etc., darker grayish; the rest of the under parts deep brownish ochraceous; the bill with the base and tip of the maxilla brownish, but with no pronounced blackish as in the young male. The color of the under parts fades very gradually as the season advances, some of my February specimens being only slightly paler than the October and November ones.

The St. Lucas Cardinal is quite as abundant and almost as widely dispersed, near the southern extremity of Lower California, as the preceding species, but being of more sedentary disposition its numbers in any given locality vary only slightly, if at all, with the different seasons. It occurs practically everywhere from the shores of the Gulf to among the foot-hills of the mountains, but apparently not on the summits or upper slopes of the latter. Mr. Frazar found it most numerously at La Paz and Triunfo, least so at San José del Cabo, while he did not meet with a single specimen on the Sierra de la Laguna. Mr. Bryant saw the bird occasionally "among thick high shrubs and trees," on Santa Margarita Island, and it was common at Comondu, while further northward he traced it nearly to latitude 29°. Like the St. Lucas Towhee it is probably confined to the Peninsula. It is represented in southern Arizona and northern Sonora respectively by the closely allied *C. c. superbus*, and in southern Sonora and Sinaloa by *C. c. affinis* and *C. c. sinaloensis*. No form of this genus is indigenous to California, but *C. cardinalis* has been introduced there, and is said to have become established in the neighborhood of Galt and Stanhope.

Mr. Frazar took four nests of *C. c. igneus* at San José del Rancho in July, the first on the 14th, the last on the 20th of the month. Three were in bushes, the fourth in a small tree, the height above the ground varying from four to ten feet. They all closely resemble nests of the eastern Cardinal. The eggs, three in number in each instance, were all fresh or but slightly incubated. They average .96 by .72 with extremes of 1.01 by .73 and .93 by .70. The color and markings vary considerably with the different specimens, all of which are closely matched by eggs of *C. cardinalis* in my collection. In fact, I cannot detect even an average difference between the eggs of the two forms, although Dr. Brewer, writing of those of *igneus* taken by Mr. Xantus, says, "Their markings are larger, and more of a rusty than an ashy brown, and the purple spots are fewer and less marked than in *C. virginianus* [*C. cardinalis*]." [1]

Pyrrhuloxia sinuata peninsulae RIDGW.

ST. LUCAS PYRRHULOXIA.

Pyrrhuloxia sinuata (not *Cardinalis sinuatus* BONAPARTE) BAIRD, Proc. Acad. Nat. Sci. Phila., 1859, 301, 304 (Cape St. Lucas). COOPER, Orn. Cal., 1870, 236, 237, part (Cape St. Lucas). COUES, Check List, 1873, 41, no. 202, part; 2d ed., 1882, 60, no. 298, part. BAIRD, BREWER, and RIDGWAY, Hist. N. Amer. Birds, II. 1874, 96, part (breeding at Cape St. Lucas; crit.). RIDGWAY, Nom. N. Amer. Birds (Bull. U. S. Nat. Mus., no. 21), 1881, 27, no. 243, part; Proc. U. S. Nat. Mus., V. 1883, 541 (crit.) BELDING, *Ibid.* (Cape Region); VI. 1883, 345 (Cape Region). SALVIN and GODMAN, Biol. Centr.-Amer., Aves, I. 1884, 343, part (Lower Calif.). A. O. U., Check List, 1886, 286, no. 594, part. SHARPE, Cat. Birds Brit. Mus., XII. 1888, 158–160, part.

[*Pyrrhuloxia*] *sinuata* COUES, Key N. Amer. Birds, 1872, 150, 151, part (Cape St. Lucas).

Pyrrhuloxia sinuata peninsulae RIDGWAY, Auk, IV. 1887, 347 (orig. descr.; type from San José); Man. N. Amer. Birds, 2d ed., 1896, 606 (descr.; S. Lower Calif.); Birds N. and Midd. Amer., pt. I. 1901, 627, 628 (descr.; Cape St. Lucas district). A. O. U. COMM., Suppl. to Check List, 1889, 14; Check List, abridged ed., 1889, and 2d. ed., 1895, no. 594 b. BRYANT, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 304 (Cape St. Lucas; Cape Region). COUES, Key N. Amer. Birds, 4th ed., 1894, 900.

[*Pyrrhuloxia sinuata*] var. *peninsula* DUBOIS, Synop. Avium, fasc. IX. 1901, 619 (Basse-Californie).

The characters by which Mr. Ridgway has proposed to distinguish the Pyrrhuloxia of Lower California prove reasonably constant in my series. The form *peninsulae*, however, does not differ nearly so much from *sinuata* as the latter does from *texana*.

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[1] Baird, Brewer, and Ridgway, Hist. N. Amer. Birds, II. 1874, 103.

Individual variations: — Spring males. Red of the crest sometimes pure dark wine color, sometimes strongly tinged with blackish. Red of the under parts sometimes pure and continuous from the chin to the crissum, sometimes interrupted by ashy on the breast and lower abdomen. Red of the capistrum usually pure, but occasionally tinged very slightly with blackish.

Spring females. Capistrum, throat, breast, abdomen, crissum, and under tail coverts sometimes plain, sometimes tinged with red.

Winter plumage: — Adult males. Crown, back, sides of neck, and entire under parts, except the throat, strongly tinged with yellowish brown or brownish olive, which, over the red of the median lower parts, forms merely a narrow tipping at the ends of the feathers.

Young males. Differing from adults in autumn only in having the red more restricted and often almost wholly concealed, on the forehead, as well as over most of the breast and lower abdomen, by the brownish tipping above mentioned.

Females. Wings and tail grayer than in spring birds, the general coloring clearer and richer, the upper parts brownish ashy, the lower parts rich buff tinged with brownish ashy on the breast and sides of neck and body; the upper tail coverts, inner secondaries, and greater and middle wing coverts, tipped with light brownish of the same shade as the back, this brownish, on the wing coverts, forming two ill-defined bands. If my series of autumnal females contains both young and adults I am unable to distinguish them.

This bird appears to be strictly confined to the Cape Region, where it is nowhere very common. Mr. Belding considered it more numerous in the interior than near the coast, but Mr. Frazar found it in the greatest numbers at Triunfo and San José del Cabo, the latter place being, of course, directly on the coast. About La Paz, however, only a single specimen was seen, and but one was obtained on the Sierra de la Laguna. At Santiago four were taken, and there is a skin in the collection from San José del Rancho. The bird is doubtless resident wherever found.

No representative of this genus is known to inhabit any part of California, but the closely related *P. sinuata* occurs in southern Arizona and western Mexico.

Zamelodia melanocephala (Swains.).

Black-headed Grosbeak.

Guiraca melanocephala Baird, Proc. Acad. Nat. Sci. Phila., 1859, 301, 304 (Cape St. Lucas).

Goniaphea melanocephala Coues and Streets, Bull. U. S. Nat. Mus., no. 7, 1877, 11 (Pichilinque Bay).

Zamelodia melanocephala Belding, Proc. U. S. Nat. Mus., V. 1883, 541 (Cape Region).

Habia melanocephala Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 304 (Cape Region).

All my males of this species from the Cape Region have tawny postocular stripes and more or less well-defined, median crown or occipital stripes or spots of the same color. It has been asserted that these markings are peculiar to the bird of Lower California and the Pacific slope of the United States and British America (for which the name *capitalis* was proposed by Baird), but, as Mr. Ridgway has recently indicated,[1] they are not always present in specimens from the regions just mentioned, nor invariably absent in those from the interior of North America and Mexico. Striking, and to my mind conclusive, proof of their fallibility as distinguishing characters is afforded by two breeding males taken at Pinos Altos, Chihuahua, Mexico, on June 5 and 8, respectively. One of these has the black of the head perfectly uniform save behind the eyes, where there are a few inconspicuous spots of tawny; in the other there is a well-marked light postocular stripe, and a broad conspicuous median patch of tawny reaching from about the center of the crown to the vertex. In other words, the former specimen is nearly typical of *melanocephala*, the latter about an average example of *capitalis.*

Mr. Frazar notes the Black-headed Grosbeak as " resident during the entire year" in the Cape Region, but his collection contains no specimen taken later in spring than May 4, nor earlier in summer than July 22. He found the species at La Paz, where it was rare in February, more numerous in March; about Santiago, where it was common in late August; at San José del Rancho, where it was frequently seen in December; and on the Sierra de la Laguna, where a single specimen was taken on May 4th.

Mr. Bryant says that "it is not common in the northwest, according to Messrs. Belding and Anthony. The former found it breeding at Valle Trinidad, and saw a single specimen on Cerros Island, and the latter at San Rafael. I obtained a single pair at Comondu April 22, 1888."

This Grosbeak breeds in the Sierra Madre Mountains as far south as Chihuahua, and I have spring specimens from Alamos, in western Mexico. It is a common summer resident of most parts of California and ranges northward into British Columbia.

Guiraca caerulea lazula (Lesson).

WESTERN BLUE GROSBEAK.

Guiraca caerulea (not *Luzula caerulea* LINNAEUS) BELDING, Proc. U. S. Nat. Mus., V. 1883, 546 (San José del Cabo).

Guiraca caerulea eurhyncha BRYANT, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 305 (San José del Cabo).

Mr. Frazar's specimens, all but one of which are either females or young males in the brown plumage, agree closely with birds in my collection from western Mexico and various localities near the southern border of the western United States.

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[1] Birds N. and Midd. Amer., pt. I. 1901, 619, footnote.

Mr. Belding, who was the first to detect this Grosbeak in Lower California, saw only two individuals, — both at San José del Cabo, in the spring of 1882. In the neighborhood of this town Mr. Frazar found the birds not uncommon in the autumn of 1887, taking no less than twelve at various dates between August 28 and November 4. A single specimen was also shot at San José del Rancho on December 20.

Mr. Bryant met with the Western Blue Grosbeak at Comondu, where "those which were taken had been feeding in a patch of growing wheat," and Mr. Anthony found it "very common in all the coast valleys from San Quintin northward."[1] It should breed on the Peninsula, but we do not know that it ever does so. It is a rather common summer resident in California, especially in the southern counties near the coast. In western Mexico my collectors have found it nesting as far south as Oposura, and have obtained specimens in winter and early spring about Alamos. Its winter range is said to extend through Central America to southern Costa Rica.

Cyanospiza amoena (Say).

Lazuli Bunting.

Passerina amoena Belding, Proc. U. S. Nat. Mus., V. 1883, 541 (Cape Region). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 305 (Cape Region).

Mr. Belding and Mr. Frazar are quite in accord respecting this species, both characterizing it as somewhat uncommon in the Cape Region. If, as seems most probable from the evidence at hand, it does not breed there, it arrives from the north rather early, for Mr. Frazar took a specimen at Triunfo on August 15. He saw the greatest number, however, at San José del Cabo in September and October. None were observed by him either at La Paz or on the Sierra de la Laguna, but two were taken at Triunfo on December 9, and a third at San José del Rancho on December 23. The last two dates indicate that at least a few birds spend the winter in this region.

Mr. Bryant found the Lazuli Bunting "rare at Comondu and northward." Mr. Anthony states that it was abundant about San Pedro Martir, where "one or two were seen on top of the mountain."[2] It breeds from southern California to British Columbia, and in winter goes as far south as Mazatlan, in western Mexico.

Cyanospiza versicolor pulchra (Ridgw.).

Beautiful Bunting.

Cyanospiza versicolor (not *Spiza versicolor* Bonaparte) Baird, Proc. Acad. Nat. Sci. Phila., 1859, 301 (Cape St. Lucas), 304 (crit.; Cape St. Lucas). Cooper, Orn. Cal., 1870, 234, 235, part (Cape St. Lucas). Baird, Brewer, and Ridg-

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[1] Zoe, IV. 1893, 243.

[2] *Ibid.*

WAY, Hist. N. Amer. Birds, II. 1874, 87, part, pl. 29, fig. 10 (breeding at Cape St. Lucas; crit.). SALVIN and GODMAN, Biol. Centr.-Amer., Aves, I. 1886, 361, 362, part (breeding at Cape St. Lucas, May 5).

Passerina versicolor (not *Spiza versicolor* BONAPARTE) BELDING, Proc. U. S. Nat. Mus., V. 1883, 546 (San José del Cabo).

P.[asserina] versicolor pulchra RIDGWAY, Man. N. Amer. Birds, 1887, 448 (orig. descr.; type from Miraflores).

Passerina versicolor pulchra BRYANT, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 305 (Cape St. Lucas; Miraflores).

Although this form has been lately given up by its original describer, Mr. Ridgway,[1] I consider it a perfectly good subspecies. Not only do the males in the large series before me exhibit, with remarkable constancy, the characters which serve to distinguish them from the males of *versicolor*, but the females, also, differ considerably in color, as well as in proportions, from those of the race just named, the female of *pulchra* being decidedly the grayer of the two, especially on the under parts and on the sides of the head and neck. Mr. Ridgway admits that "were it not for the intermediate character of specimens from western Mexico it would be comparatively easy to characterize a subspecies, *C. versicolor pulchra*, for the Lower California bird." I fail to see, however, why the fact that *an intermediate region* furnishes more or less intermediate specimens should affect the status of the forms in question to a greater degree than that of showing that they are not specifically distinct.

Winter plumage: — Adult male (No. 16,355, San José del Cabo, October 8, 1887). With the blue of the rump less purplish than in spring; the purple of the under parts deeper and duller; the inner secondaries, wing coverts and feathers of the crown, nape, back, rump, and entire under parts (excepting the chin) more or less broadly tipped with brownish olive, this tipping heaviest on the back, where it almost wholly conceals the purplish beneath. Another specimen (No. 16,264, Triunfo, December 6, 1887) has the brown confined to the occiput, nape, back, wings, sides of the neck, jugulum, and sides of the body; the rump, forehead, crown, sides of the head, and middle part of the abdomen being nearly as purely colored as in spring.

Young female (No. 16,359, Santiago, November 18, 1887). Above bister, the wings and tail ashy brown, the inner secondaries and greater and middle wing coverts edged and tipped with clayey brown; beneath brownish clay color, deepest on the sides of the neck and body and across the breast, palest on the abdomen, anal region, and crissum.

In the plumage just described the female of this species is exceedingly difficult to separate from autumnal females of *C. amoena*. The latter, however, usually have the wings more bluish and the general coloring brighter and more ochraceous. Moreover, the difference in size, and especially in the size and shape of the bill, can usually be relied upon to distinguish the two forms.

The collection contains no specimen of the young male in winter plumage, but it furnishes a dozen or more spring males in immature plumage. These birds vary exceedingly in coloring, no two of them being precisely alike. Some of the duller specimens resemble the adult female, from which, however, they can be easily distinguished by the reddish tinge of their crowns and cheeks. Others again are mottled with dull purple on the throat and sides of the head, with lavender blue on the crown. In still others the entire plumage of the body is variegated with various shades of blue, purple, and brown, presenting a curiously piebald appearance.

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[1] Birds N. and Midd. Amer., pt. I. 1901, 592.

In Lower California, this bird, as far as known, is strictly confined to the Cape Region. Indeed, it does not appear to range even so far northward as La Paz. Mr. Belding mentions it only in his list of "species found at San José del Cabo from April 1 to May 17," and characterizes it as "rare." Mr. Frazar met with it first at Triunfo, where three were taken on April 13, and where it soon became so abundant that "over one hundred were seen on April 21." Through June and July it was less numerous, but yet very common here as well as at Pierce's Ranch. At San José del Cabo a specimen was shot late in August and two others early in October, while in December four were taken at Triunfo and two at San José del Rancho; the last on the 23d. These dates indicate that at least some of the birds are resident, but Mr. Frazar thinks that by far the greater number leave Lower California in autumn and pass the winter elsewhere, probably in western Mexico. From the latter region I have a large series of specimens, including several taken in winter (February) at Alamos, and in May and June near Oposura.

"Though found close up to the Texan frontier of the United States, the only claim *C. versicolor* had for a long time to be included in the birds of North America was its occurrence in the peninsula of Lower California, where it breeds, Mr. Xantus having found a nest and three eggs on May 5th at Cape San Lucas."[1]

Spiza americana (Gmel.).

Dickcissel.

This species, new to Lower California, is represented in Mr. Frazar's collection by a single female, taken at San José del Cabo on September 27, 1887. No others were seen, and the bird just mentioned was doubtless a mere waif which had lost its way and wandered from the usual path of migration, for *S. americana* is practically unknown west of the Rocky Mountains[2] in the United States, and none of my collectors have obtained it in western Mexico. Colonel Grayson, however, records two specimens taken near Mazatlan "in the month of August,"[1] and a few were observed in Guatemala, near the Pacific coast, by Salvin and Godman.[2] Further to the southward, in Central America, the bird is generally distributed and very plentiful in winter.

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[1] Salvin and Godman, Biol. Centr.-Amer., Aves, I. 1886, 361, 362.

[2] One of the most western records is that by Mr. Scott (Auk, IV. 1887, 205) of a female taken by Mr. Herbert Brown, near Tucson, Arizona, on September 11, 1884.

Calamospiza melanocorys Stejn.

Lark Bunting.

Calamospiza bicolor Baird, Proc. Acad. Nat. Sci. Phila., 1859, 301, 304 (Cape St. Lucas). Coues and Streets, Bull. U. S. Nat. Mus., no. 7, 1877, 11 (Pichilinque Bay). Belding, Proc. U. S. Nat. Mus., V. 1883, 541 (Cape Region).
Calamospiza melanocorys Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 305 (Cape Region).

Lark Buntings are abundant throughout most of Lower California during the autumn and spring migrations. In the Cape Region, however, Mr. Frazar found them only at San José del Cabo, where the first was seen on September 27. During October they were exceedingly numerous, and were usually found in large flocks. None were observed after November 8, but as Mr. Bryant noted a flock on Santa Margarita Island as early as March 1, and as I have several specimens taken in January at Guaymas on the eastern shore of the Gulf of California (about latitude 28° north), it is not improbable that some remain in the Cape Region through the entire winter.

This species occurs in California only during migration, and then chiefly in the southern counties and in no very great numbers. It breeds principally east of the Rocky Mountains. It has not been recorded from western Mexico south of Guaymas, but in the interior of that country has been found as far south as Guanajuato.

Piranga ludoviciana (Wils.).

Louisiana Tanager.

Pyranga ludoviciana Ridgway, Proc. U. S. Nat. Mus., V. 1883, 533, footnote (Cape St. Lucas). Belding, *Ibid.*, VI. 1883, 347 (Victoria Mts.; La Paz).
Piranga ludoviciana Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 305 (Cape St. Lucas; Victoria Mts.; La Paz).

Mr. Xantus found the Louisiana Tanager at Cape St. Lucas between September 27 and November 17. Mr. Belding gives it as rare at La Paz and also among the "Victoria Mountains" (Bryant), presumably in late winter and early spring, although no dates are mentioned. Mr. Frazar notes it as not very uncommon at Miraflores in November, and at San José del Rancho in December. At the latter place, on July 29, he killed a female which "was evidently nesting." The bird may be briefly characterized, therefore, as a somewhat uncommon winter, and rare summer resident. To the northward, according to Mr. Bryant, it has been met with at only a few places, and nowhere numerously. Mr. Anthony states that he found it "quite common" at San Pedro Martir in late April and early May, 1893, but that it was "not seen above 7,000 feet."[1]

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[1] Lawrence, Mem. Bost. Soc. Nat. Hist., II. 1874, 277.

[2] Biol. Centr.-Amer., Aves, I. 1886, 417.

In California, the Louisiana Tanager occurs only in summer and at its seasons of migration. It is rather rare near the coast, but has been found breeding at Santa Barbara. In the interior it breeds commonly among the Sierras. Northward its range extends into British Columbia. It goes as far south as Guatemala, and is common in western Mexico in spring and autumn.

Progne subis hesperia Brewst.

Western Martin.

Progne purpurea (not *Hirundo purpurea* Catesby) Baird, Proc. Acad. Nat. Sci. Phila., 1859, 301, 303 (Cape St. Lucas).

Progne subis (not *Hirundo subis* Linnaeus) Baird, Rev. Amer. Birds, pt. I. 1865, 274–277, part (Cape St. Lucas). Belding, Proc. U. S. Nat. Mus., V. 1883, 547 (San José).

Progne subis hesperia Brewster, Auk, VI. 1889, 92, 93 (orig. descr.; types from Sierra de la Laguna). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 306 (Cape St. Lucas; San José del Cabo; Sierra de la Laguna); Zoe, II. 1891, 195 (San José del Cabo).

This subspecies, in which the differential characters are exhibited by the female only, was first met with by Mr. Frazar on the summit of the Sierra de la Laguna, where it appeared on April 29. Regularly each afternoon, during May and the first week of June, a few congregated over an open space in front of a hunter's cabin. They usually flew at a considerable height, but the males every now and then pitched downward nearly to the earth, descending with great velocity and making a booming noise very like that of the eastern Nighthawk. This remarkable habit, unknown in the common Martin, was constantly practised here, but, curiously enough, it was not once observed at Triunfo, where Mr. Frazar found the Western Martins abundant during the last three weeks of June. Belonging to the mine at this latter place, was an immense wood-pile covering over three acres and harboring great numbers of long-horned beetles upon which the Martins and Texan Nighthawks fed greedily. The Martins appeared every afternoon, a little before sunset, to the number of two or three hundred, and skimmed back and forth over the wood-pile until twilight fell. Mr. Frazar was told that they were first seen here about the date when they arrived on La Laguna. They disappeared suddenly and totally, immediately after a succession of heavy showers early in July, and were not afterwards met with excepting at San José del Cabo, where a few, evidently migrating, were seen passing southward in late August and early September.

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[1] Zoe, IV. 1893, 243.

Mr. Bryant records the Western Martin from several places in the northern portions of Lower California, and says that it has been found nesting by Mr. Belding in dead pines at Hansen's. Mr. Anthony states that in the neighborhood of San Fernando, it is "not uncommon at the mission and an occasional pair was seen in other localities, nesting in Woodpecker holes in the giant cactus,"[1] while on San Pedro Martir it is "very common; nesting in colonies from Valladares, 2,500 feet altitude, throughout the pines."[2] Mr. Frazar's experience indicates, of course, that the bird also breeds in the Cape Region, but he obtained no direct proof of this.

The Western Martin occurs in summer throughout most of California, and probably still further northward. Its winter haunts are not definitely known.

Petrochelidon lunifrons (Say).

Cliff Swallow.

Petrochelidon lunifrons Belding, Proc. U. S. Nat. Mus., V. 1883, 547 (San José del Cabo). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 306 (San José del Cabo).

Two Cliff Swallows taken by Mr. Frazar, both young birds with white-spotted throats, are very much paler than any of my eastern examples in corresponding plumage. In both, the rump is dull ochraceous buff, the forehead, nuchal collar, breast, and sides, pale drab gray with a slight tinge of rufous. The only decided rufous is on the throat and sides of the head. These specimens are almost perfectly matched by a bird (No. 30,556) in the United States National Museum, labeled as taken "at sea off the west coast of Central America, Oct. 20, 1863." It is not improbable that all three belong to a form as yet undescribed, or possibly they may be the young of some of the known Mexican and Central American species of which I have seen only the adults.

Mr. Belding mentions seeing the Cliff Swallow on April 29, 1882, at San José del Cabo, where Mr. Frazar found it very numerous between September 8 and October 7, 1887. It occurred in large, straggling flocks which usually contained varying percentages of other species of Swallows, most of which were either migrating or collecting at this point preparatory to setting out across the sea. Neither of the observers just mentioned met with the Cliff Swallow at any other locality in the Cape Region. To the northward, however, it has been found at San Quintin Bay in May by Mr. Belding (fide Bryant) and at San Fernando[3] and San Pedro Martir by Mr. Anthony. At the locality last named it was "common in colonies from the coast to the top of the mountain;

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[1] Auk, XII. 1895, 141.

[2] Zoe, IV. 1893, 243.

[3] Auk, XII. 1895, 141.

. . . nesting on the sides of huge granite boulders in meadows of La Grulla May 13, and later on the eastern side."[1] It breeds abundantly throughout most of California and thence northward into Alaska, and goes as far south as Paraguay and Brazil in winter.

Hirundo erythrogaster Bodd.

BARN SWALLOW.

Mr. Frazar killed two Barn Swallows at Triunfo on April 24, but met with no others until August 28, when, on reaching the sea-coast, he found the bird at San José del Cabo. During September it was seen almost daily, usually in company with Cliff Swallows. Both species fluctuated considerably in numbers from time to time, for successive migrating flights were continually arriving and passing on, but the Barn Swallows, on the whole, kept increasing up to September 27, when they were really abundant. An interval of comparative scarcity followed, but they again became very numerous on October 10, the latest date under which the species is mentioned in Mr. Frazar's notes.

Although the Barn Swallow is here reported for the first time from the Cape Region, it has been seen further to the northward on the Peninsula: — at San Quintin, in May, 1881, by Mr. Belding; at San Jorge, in March, 1888, by Mr. Bryant; on San Pedro Martir and along the neighboring coast in April and May, 1893, by Mr. Anthony. It is very generally distributed, and rather common in summer, in California, and breeds as far northward as Alaska. Its winter range extends into South America.

Tachycineta bicolor (Vieill.).

TREE SWALLOW.

Tachycineta bicolor BELDING, Proc. U. S. Nat. Mus., V. 1883, 537 (Cape Region). BRYANT, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 306 (Cape Region).

This Swallow was "often seen in winter" in the Cape Region by Mr. Belding, in 1881–82, but no one else appears to have met with it in any part of Lower California. Mr. Frazar, who looked for it very carefully, but vainly, is strongly of the opinion that the record just quoted requires confirmation. There is no apparent reason, however, why the bird should not visit Lower California, for it is not uncommon in California proper, and is known to migrate as far southward as Guatemala.

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[1] Zoe, IV. 1893, 243.

Tachycineta thalassina lepida (Mearns).

NORTHERN VIOLET-GREEN SWALLOW.

(?) *Hirundo thalassina* Baird, Proc. Acad. Nat. Sci. Phila, 1859, 301, 303, part (Cape St. Lucas); Rev. Amer. Birds, pt. I. 1865, 299 part (crit.; Cape St. Lucas; San José).

(?) *Tachycineta thalassina* Belding, Proc. U. S. Nat. Mus., V. 1883, 537, part (Cape Region). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 306, part (Cape Region).

Dr. Mearns has recently separated the Violet-green Swallow which breeds throughout the western United States from that inhabiting the southern tablelands of Mexico, restricting the name *thalassina* to the latter and bestowing on the former the name *lepida*.[1] He considers the two birds specifically distinct, but his text indicates that some of the specimens which he examined from northern Mexico were really intergrades, and I have others from the same region which unquestionably must be so regarded.

Mr. Frazar took a typical female of *lepida* at La Paz on February 14. This, so far as I know, is the only specimen which has been thus far obtained in the Cape Region, but there can be little doubt that *lepida* occurs there more or less regularly and numerously in winter or during migration. Mr. Nelson writes me that it is the characteristic form of northern Lower California, from which we may infer that it was the bird found by Mr. Anthony about San Pedro Martir "nesting in hollow pines," and "very abundant from Valladares to the top of the mountain."[2]

Tachycineta thalassina brachyptera, subsp. nov.

ST. LUCAS SWALLOW.

Hirundo thalassina Baird, Cat. N. Amer. Birds, 1859, no. 228, part; Proc. Acad. Nat. Sci. Phila., 1859, 301, 303, part at least (Cape St. Lucas); Rev. Amer. Birds, pt. I. 1865, 299, part at least (crit.; Cape St. Lucas; San José). Baird, Brewer, and Ridgway, Hist. N. Amer. Birds, I. 1874, 347–349, part.

[*Tachycineta*] *thalassina* Coues, Key N. Amer. Birds, 1872, 113, part.

Tachycineta thalassina Coues, Check List, 1873, 23, no. 113, part; 2d ed., 1882, 42, no. 161, part. Ridgway, Nom. N. Amer. Birds (Bull. U. S. Nat. Mus., no. 21), 1881, 20, no. 156, part. Belding, Proc. U. S. Nat. Mus., V. 1883, 537,

[1] Proc. Biol. Soc. Wash., XV. 1902, 31, 32.

[2] Zoe, IV. 1893, 243

part at least (Cape Region). BRYANT, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 306, part at least (Cape Region).

Tachycineta thalassinus SHARPE, Cat. Birds Brit. Mus., X. 1885, 119–121, part.

T.[*achycineta*] *thalassina* COUES, Key N. Amer. Birds, 4th ed., 1894, 323, part. RIDGWAY, Man. N. Amer. Birds, 2d ed., 1896, 462, part.

Subspecific characters: — Similar to *T. lepida* Mearns, but with the wing decidedly and apparently constantly shorter.

Type ♂ ad. No. 15,406. Collection of William Brewster, Sierra de la Laguna, Lower California, June 6, 1887, M. Abbott Frazar.

Measurements: —

Mus. No.	Sex	Locality	Date	Wing	Tail
15,401[1]	♂	Sierra de la Laguna, Lower Cal.	June 4, 1887	4.35	1.88
15,400[1]	♂	“ “ “ “ “ “	“ “ “	4.24	1.89
15,397[1]	♂	“ “ “ “ “ “	May 11, “	4.20	2.00
15,405[1]	♂	“ “ “ “ “ “	June 6, “	4.20	1.82
15,399[1]	♂	“ “ “ “ “ “	“ 2, “	4.19	1.91
15,398[1]	♂	“ “ “ “ “ “	May 11, “	4.18	2.09
15,402[1]	♂	“ “ “ “ “ “	June 4, “	4.16	1.76
15,396[1]	♂	“ “ “ “ “ “	April 29, “	4.15	1 93
15,403[1]	♂	“ “ “ “ “ “	June 4, “	4.13	1.91
15,404[1]	♂	“ “ “ “ “ “	“ 6, “	4.09	1.76
15,406[1]	♂	“ “ “ “ “ “	“ “ “	4.07	1.73
15,412[1]	♂	Triunfo, “ “	April 15, “	4.21	1.85
15,414[1]	♂	“ “ “	June 24, “	4.18	1.75
15,411[1]	♂	“ “ “	April 15, “	4.10	1.87
15,413[1]	♂	“ “ “	“ “ “	4.08	1.84
15,417[1]	♂	La Paz, “ “	Feb. 4, “	4.13	1.79
15,420[1]	♂	“ “ “ “	March 28, “	4.12	1.87
15,419[1]	♂	“ “ “ “	Feb. 14, “	4.09	1.80
15,418[1]	♂	“ “ “ “	“ “ “	3.98	1.78
			Average,	4.15	1.85+
15,407[1]	♀	Sierra de la Laguna, Lower Cal.	June 2, 1887	4.11	1.76
15,408[1]	♀	“ “ “ “ “ “	“ 4, “	4.05	1.69
15,409[1]	♀	“ “ “ “ “ “	“ “ “	3.95	1.67
15,410[1]	♀	“ “ “ “ “ “	“ 6, “	3.94	1.65
15,415[1]	♀	Triunfo, “ “	April 15, “	4.09	1.77
15,416[1]	♀	“ “ “	“ “ “	4.07	1.77
15,423[1]	♀	La Paz, “ “	Feb. 14, “	4.25	1 80
15,421[1]	♀	“ “ “ “	March 28, “	3.98	1.70
15,422[1]	♀	“ “ “ “	Feb. 14, “	3.90	1.68
			Average,	4.04–	1.72+

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[1] Collection William Brewster.

Tachycineta thalassina lepida.

Mus. No.	Sex	Locality	Date	Wing	Tail
42,416[1]	♂	Sebastopol, Cal.	April 19, 1885	4.62	1.92
13,222[1]	♂	“ “	“ 20, 1886	4.51	1.87
13,220[1]	♂	“ “	“ “ “	4.50	1.94
13,221[1]	♂	“ “	May 26, 1885	4 26	1.90
678[1]	♂	Marin Co., “	Sept. 3, 1878	4.57	1.95
5,255[1]	♂	“ “ “	April 16, 1880	4.53	1.86
5,336[1]	♂	“ “ “	March 30, 1883	4.52	1.98
679[1]	♂	“ “ “	Sept. 3, 1878	4.43	1.93
——[1]	♂	Huachuca Mts., Arizona	May 24, 1888	4.58	1.89
45,516[1]	♂	Brit. Columbia	April 12, 1888	4.80	1.80
47,363[1]	♂	Sumas, “ “	May 5, 1897	4.72	2.00
45,515[1]	♂	Chilliwack, “ “	April 9, 1891	4.50	1.80
21,946[1]	♂	Pinos Altos, Mexico	June 8, 1888	4.50	1.90
15,499[2]	♂	Deer Creek, Col.	July 10, 1871	4.54	1.99
15,497[2]	♂	“ “ “	“ “ “	4.51	1.75
15,498[2]	♂	“ “ “	“ “ “	4.50	1.90
15,496[2]	♂	“ “ “	“ “ “	4.45	1.80
——[2]	♂	Nicasio, Cal.	May 9, 1879	4.78	1.98
33,299[2]	♂	“ “	“ “ “	4.70	1.95
			Average,	4.55+	1.90+
675[1]	♀	Mill City, Col.	May 24, 1877	4.54	1.89
5,899[1]	♀	Cienega Station, Arizona	April 16, 1881	4.28	1.79
676[1]	♀	Marin Co., Cal.	June 12, 1877	4.10	1.73
33,298[2]	♀	Nicasio, Cal.	April 12, 1879	4.41	1.72
			Average,	4.33+	1.78+

The Violet-green Swallow of the Cape Region furnishes an interesting illustration of the recognized fact that isolated, non-migratory birds are given to having shorter wings than those which regularly perform extended journeys, for in respect to the length of the wing it is almost if not quite as much smaller than the form which breeds in the regions lying further to the northward (*i. e.* California, Oregon, Washington, and British Columbia) as the latter is smaller than true *thalassina* of the Mexican table-land still further to the southward. This difference, shown in the foregoing tables of measurements, is the only essential one which I am able to find between *lepida* and *brachyptera*. In the material which I have examined it appears to be not only marked but constant. There can be little question, however, that the two birds really come together and intergrade in the central portions of the Peninsula.

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[1] Collection William Brewster.

[2] Collection Mus. Comp. Zoöl.

This is the characteristic Swallow of the Cape Region, if not the only representative of the Hirundinidae, excepting the Western Martin, which breeds there regularly and plentifully. About La Paz and other places on or near the coast it perhaps occurs only in winter, as Mr. Belding indicates, but Mr. Frazar found it common on the Sierra de la Laguna in May and early June, and at Triunfo and San José del Rancho in late June and July. On the summit of La Laguna it was nesting late in May, and one was seen flying over the highest peak of this mountain on December 2, while, "at the same time, the sunlight glistened on the backs of others skimming about a cañon six or eight hundred feet below." None were observed at San José del Cabo in early autumn among the hordes of migrating Barn and Cliff Swallows, but a flock was noted at Santiago on November 23.

It is not probable that *brachyptera* ranges far to the northward of the Cape Region, but it is likely to have been the Violet-green Swallow which Mr. Bryant found "nesting in the holes made by the Gila Woodpecker in giant cacti," near Comondu.

Riparia riparia (Linn.).

Bank Swallow.

Clivicola riparia Bryant, Zoe, II. 1891, 195 (San José del Cabo).

Mr. Bryant seems to be the only observer who has met with the Bank Swallow in the Cape Region or, indeed, in any part of Lower California. He states that at evening, for a week or two during the early part of September, 1890, he "witnessed a remarkable flight of swallows, as they followed the course of the river" at San José del Cabo. "The birds were principally bank swallows (*Clivicola riparia*), with some rough-winged swallows (*Stelgidopteryx serripennis*) among them, and occasionally the large western purple martins (*Progne subis hesperia*) were associated with the thousands of swallows; about sundown the air seemed filled with swallows where during the day they were not abundant."

The occurrence of this species in Lower California is not surprising, for its general range along or near the Pacific coast extends from Alaska to Costa Rica.

Stelgidopteryx serripennis (Aud.).

Rough-winged Swallow.

Stelgidopteryx serripennis Bryant, Zoe, II. 1891, 195 (San José del Cabo).

The Rough-winged Swallow is represented in Mr. Frazar's collection by three specimens, all young males killed at San José del Cabo late in August, — two on the 23d, and the third on the 25th. In his journal, under date of

August 28, the species is noted as "very abundant," but is not afterwards mentioned. Mr. Bryant found it in moderate numbers at the same locality during the early part of September, 1890.

This Swallow ranges as far north on the Pacific coast as British Columbia, and as far south as Guatemala. In California it is rather common and widely distributed in summer.

Ampelis cedrorum (Vieill.).

Cedar Waxwing.

Ampelis cedrorum Belding, Proc. U. S. Nat. Mus., V. 1883, 537 (Cape Region). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 306, 307 (Cape Region).

Mr. Belding gives the Cedar Waxwing as "very rare" in the Cape Region, a statement confirmed by the experience of Mr. Frazar, who met with the bird on but one occasion, at San José del Rancho on December 22, when two specimens were taken from a flock containing about a dozen. Mr. Bryant mentions seeing a small flock at Comondu on April 7, 1888, and Mr. Anthony found the species "rather common about Valladares" in late April and early May, 1893.[1]

In California the Cedar Waxwing is known only as an irregular and rather infrequent winter visitor, but it breeds commonly in portions of Oregon and northward into British Columbia.[2] In winter it migrates as far southward as Guatemala and Honduras.

Phainopepla nitens (Swains.).

Phainopepla.

Phainopepla nitens Baird, Proc. Acad. Nat. Sci. Phila., 1859, 301, 303 (Cape St. Lucas). Belding, Proc. U. S. Nat. Mus., V. 1883, 534 (Cape Region); VI. 1883, 345 (Cape Region). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 307 (Cape St. Lucas; Cape Region).

Phaenopepla nitens Baird, Rev. Amer. Birds, pt. I. 1866, 416 (descr.; Cape St. Lucas).

This species is resident in the Cape Region, and apparently about equally common there at all seasons. It is represented in Mr. Frazar's collection by a large series of specimens, most of which were obtained at San José del Rancho in July, and at La Paz in February, March, and April. I have also two examples which were shot at Triunfo in June, and two others taken in the

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[1] Zoe, IV. 1893, 243.

[2] In a late number of the Condor (III. 1901, 146, 147) Mr. Grinnell gives a full and interesting statement of the distribution of the Cedar Bird in California and to the northward near the Pacific coast.

Victoria Mountains (opposite Carmen Island) in early March. The bird appears to be chiefly confined to the foot-hills of the mountains, and to the arid region lying between them and the coast, for neither Mr. Belding nor Mr. Frazar found it on the Sierra de la Laguna. The former observer mentions it among the species which he noted along the Pacific coast between Cape St. Lucas and a point thirty miles to the northward of Todos Santos. Mr. Bryant states that it is "common near La Giganta (San Pedro and San Julio plains)," and that Mr. Anthony met with it "from Ensenada southward, up to an altitude of 6,000 feet . . . usually in mesquite thickets."

The Phainopepla is a common resident of most of southern California as well as of the greater part of Mexico.

Lanius ludovicianus excubitorides (Swains.).

White-rumped Shrike.

(?) *Collurio excubitorides* Baird, Rev. Amer. Birds, pt. I. 1866, 445–450 (crit.; Cape St. Lucas; San Nicolas).

Lanius ludovicianus excubitorides Belding, Proc. U. S. Nat. Mus., V. 1883, 537, part at least (Cape Region).

Lanius ludovicianus gambeli (not of Ridgway) Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 307, part at least (Cape Region).

Mr. Belding asserts that this form is "common" in the Cape Region, but Mr. Bryant omits it altogether from his catalogue, and cites Mr. Belding's mention under *gambeli*. Mr. Frazar's collection, however, contains two unmistakable specimens of *excubitorides*, both males taken at Triunfo on December 12 and 14 respectively. Hence the "white-rumped" bird must be restored to the list; but whether it breeds in this region or visits it only in winter, remains to be ascertained. It "occurs in the eastern and sometimes also the central portions" of California, while *gambeli* "belongs chiefly to the coast district" of that State, according to Mr. Ridgway, as quoted by Mr. Keeler.[1] I have numerous winter specimens of *excubitorides* from Guaymas and Alamos, western Mexico, and others have been taken at Mazatlan.

Lanius ludovicianus gambeli Ridgw.

California Shrike.

(?) *Collurio excubitorides* (not *Lanius excubitorides* Swainson) Baird, Rev. Amer. Birds, pt. I. 1866, 445–450 (crit.; Cape St. Lucas; San Nicolas).

(?) *Lanius ludovicianus excubitorides* Belding, Proc. U. S. Nat. Mus., V. 1883, 537, part (Cape Region).

(?) *Lanius ludovicianus gambeli* Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 307, part (Cape Region).

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[1] Zoe, I. 1890, 251.

Mr. Ridgway in the Manual[1] restricts the distribution of *L. l. gambeli* to "California, especially coast district," at the same time including Lower California in the habitat of *excubitorides*, but the majority of the Shrikes collected by Mr. Frazar are certainly *gambeli*. They are quite as dark both above and beneath as any of my California examples, and, like the latter, are very distinctly "undulated on the breast with grayish." The series contains several specimens, however, which are variously intermediate between the two forms just mentioned, and one bird (male, No. 15,433, Triunfo, December 14, 1883), which has the gray of the upper parts nearly as pure and light, and the white of the lower parts almost as clear, as in the most extreme representatives of *excubitorides*. To this form it must be referred, despite the fact that it shows a few faint transverse lines on the breast and sides, — a feature by no means uncommon in autumnal specimens of *excubitorides*.

Two birds (Nos. 86,256 ♂, and 86,257 ♀) in the National Museum Collection, both taken at La Paz, on December 15, 1881, by Mr. Belding, are also referable to *excubitorides*, although neither is typical of that form. A third example (No. 26,438) without date, obtained by Xantus at Todos Santos, is in excessively worn plumage and looks like a breeding bird. The feathers are so ragged and faded that their original coloring can only be guessed at. This specimen is remarkable in respect to its bill, which in length exceeds that of any representative of the *ludovicianus* group which I have examined, while its depth is also exceptional, as will be seen by the following measurements: — Length of culmen from base, .97; from feathers, .73; from nostril, .55; depth of bill at nostril, .38.

This is the common and characteristic Shrike of the Cape Region, where, however, according to Mr. Frazar, it does not breed, all the birds which he met with being observed in autumn, winter, or early spring. Their southward migration evidently begins at a rather early date, for he noted a specimen at San José del Cabo on August 31, and a "marked increase" in numbers by September 10. They were rather rare at Triunfo in December, but very common about La Paz in January and February. Mr. Bryant "found on Cerros, Guadalupe, and Santa Margarita Islands, and in several places on the peninsula, birds which have been referred to this race. Some Mexican children at Juncal had six young in a cage, supposing they were mocking-birds." The last statement establishes the fact that some form of Lanius breeds at Juncal, which is near the Pacific coast of the Peninsula opposite Magdalena Island, and hence not far to the northward of the Cape Region, but whether or not Mr. Bryant was correct in referring the young which he saw to *gambeli* is perhaps open to question. He states that Mr. Anthony has met with the latter race "along the entire northwestern coast region" of Lower California.

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[1] Man. N. Amer. Birds, 2d ed., 1896, 467.

Vireo gilvus swainsoni (Baird).

WESTERN WARBLING VIREO.

Vireosylvia gilva swainsoni Belding, Proc. U. S. Nat. Mus., V. 1883, 549 (Miraflores).
Vireo gilvus swainsoni Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 307 (Miraflores).

Although of late denied recognition by many ornithologists, the form *swainsoni* is, in my opinion, a good subspecies. Of the several characters which have been claimed for it the best are those relating to the bill, which is almost invariably smaller, more depressed, and darker-colored than in true *gilvus*. The Lower California bird does not appear to differ materially from that of California, Oregon, and Washington, but all my specimens from the Pacific slope north of Mexico are smaller than those from the Rocky Mountains, while the latter, in turn, are very decidedly inferior in size to some breeding examples in my collection obtained by Mr. Frazar among the Sierra Madre Mountains of Chihuahua, Mexico.

Mr. Frazar found the Western Warbling Vireo common on the Sierra de la Laguna in May and early June, and at San José del Rancho in July. It was less numerous at Triunfo, probably because of the scarcity of trees in that locality. On La Laguna the birds were paired and apparently about to breed by the middle of May, but at San José del Rancho and Triunfo none were found nesting until the middle of July. It was an easy matter to discover their nests, for the male, like that of our eastern form, is in the habit of singing while taking his turn at covering the eggs.

This Vireo may prove to be resident in the Cape Region, for Mr. Frazar shot a male at San José del Rancho on December 23. To the northward it has apparently been detected at but two localities on the Peninsula, — Comondu, where a single specimen was taken on April 12, 1888, by Mr. Bryant, and San Fernando, where Mr. Anthony states that it occurs only during migration, and then but rarely.[1]

V. g. swainsoni is a common summer bird in California and northward to British Columbia. It migrates as far southward as the Isthmus of Tehuantepec.

Vireo solitarius lucasanus Brewst.

ST. LUCAS SOLITARY VIREO.

Vireosylvia solitaria Baird, Rev. Amer. Birds, pt. I. 1866, 347, 348, part (Cape St. Lucas).
[*Vireo*] *solitarius* Coues, Key N. Amer. Birds, 1872, 121, 122, part.
Vireo solitarius Coues, Check List, 1873, 25, no. 127, part.

[1] Auk, XII. 1895, 142.

Lanivireo solitarius cassini (not *Vireo cassinii* XANTUS) RIDGWAY, Nom. N. Amer. Birds (Bull. U. S. Nat. Mus., no. 21), 1881, 19, no. 141 a, part. BELDING, Proc. U. S. Nat. Mus., V. 1883, 546 (breeding at San José del Cabo; Miraflores).

Vireo solitarius cassini COUES, Check List, 2d ed., 1882, 44, no. 178, part.

Vireo solitarius cassinii (not *Vireo cassinii* XANTUS) BRYANT, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 307 (breeding at San José del Cabo; Miraflores).

Vireo solitarius lucasanus BREWSTER, Auk, VIII. 1891, 147, 148 (orig. descr.; types from San José del Rancho and Triunfo). A. O. U. COMM., Auk, IX. 1892, 106, no. 629 d; Check List, 2d ed., 1895, 265, no. 629 d. RIDGWAY, Man. N. Amer. Birds, 2d ed., 1896, 607 (descr.; Lower Calif.).

[*Vireo solitarius*] var. *lucasana* DUBOIS, Synop. Avium, fasc. VII. 1901, 472 (Basse-Californie).

So far as known, this Vireo is strictly confined to the Cape Region, where it is found at all seasons of the year, although most numerously, perhaps, in summer. Its breeding range extends from the coast at San José del Cabo, where it occurs almost exclusively in cultivated grounds about houses, to Miraflores and San José del Rancho, at both of which places it is common. Only a few were seen by Mr. Frazar at Triunfo, and none on the Sierra de la Laguna, while but one bird was taken (on April 4) at La Paz, which appears to be beyond the northern limits of its usual range. At San José del Rancho two specimens were killed in December, one on the 20th, the other on the 23d. No form of *V. solitarius* is recorded by Mr. Bryant from anywhere north of La Paz in Lower California, but Mr. Belding reports that Colonel Goss found *V. s. cassinii* at Tia Juana, on March 20,[1] and Mr. Anthony states that at San Pedro Martir it was "not uncommon in the pines where it was first seen May 13," and where "it became more common a week or so later."[2] It is a common summer resident of portions of California, and may occasionally visit the Cape Region of Lower California during migration or in winter.

A nest of *V. s. lucasanus* containing four fresh eggs, found by Mr. Frazar at San José del Rancho on July 15, was suspended in a fork at the extremity of a long, *leafless* branch of an oak at a height of about fifteen feet. It is composed chiefly of a gray, hemp-like fiber mixed with grass stems and thin strips of bark. There are also a few spiders' cocoons loosely attached to the bottom and sides, and apparently intended as ornaments. The interior is very neatly lined with fine, wiry, reddish-brown grass circularly arranged. This nest measures externally 3.00 in diameter by 2.50 in depth; internally, 2.00 in diameter by 1.50 in depth. The walls are half an inch thick in places. The eggs measure respectively: .79 × .56, .79 × .57, .80 × .57, and .80 × 58. They are white, with a slight creamy tint, and are spotted, chiefly about the larger ends, with reddish brown and black. Both nest and eggs are very like those of *V. solitarius*.

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[1] Occ. Papers Calif. Acad. Sci., II., Land Birds Pacif. District, 1890, 201.

[2] Zoe, IV. 1893, 244.

Vireo huttoni stephensi Brewst.

Stephens's Vireo.

Vireo huttoni stephensi Belding, Proc. U. S. Nat. Mus., VI. 1883, 347 (Victoria Mts.). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 307 (Victoria Mts.).

Lower California specimens of Stephens's Vireo have larger bills than those from Arizona, but I can discover no other differences. A young bird in juvenal plumage (No. 10,248, Santa Rita Mountains, Arizona, July 9, 1884, F. Stephens) differs from the adult in having the outer edges of the wing quills and tail feathers olive green; the upper tail coverts tinged with olive; the back, nape, and crown suffused with drab; the wing bands yellowish; and the under parts lighter, the middle of the abdomen and breast being nearly pure white.

Autumnal birds in winter plumage, of which the Lower California collection contains several representatives, show a tinge of olive above and more or less brownish beneath, while the outer edges of the wings and tail are greenish olive, as with the young in juvenal plumage. The deepest colored autumnal specimens, however, are much paler and grayer than any of my examples of *V. huttoni.*

Mr. Belding, who was the first to detect Stephens's Vireo in Lower California, gives it in his list of mountain birds as "common above 3,000 feet altitude," but "not observed below this." Mr. Frazar found it numerous among the pines on the Sierra de la Laguna in May and early June, but none of the specimens killed there showed any signs of breeding. He also met with it at San José del Rancho in July, although not in any numbers. During his second visit to La Laguna, the last week of November, two birds were shot and several others seen on the very summit of this mountain, and a few days later (on December 2) a single specimen was taken at Triunfo, indicating that at least a few individuals winter in the Cape Region, to the northward of which, on the Peninsula, this Vireo has not yet been noted. It inhabits southern Arizona, and is a common bird in many parts of western Mexico.

Vireo pusillus Coues.

Least Vireo.

Vireo pusillus Belding, Proc. U. S. Nat. Mus., V. 1883, 537 (Cape Region). Baird, Brewer, and Ridgway, Hist. N. Amer. Birds, I. 1874, 391–393, pl. 17, fig. 14 (descr.: Cape St. Lucas).

Vireo bellii pusillus Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 308 (Cape Region).

Mr. Grinnell has recently separated the Least Vireo of California from that of "Arizona and southern Lower California," under the name *Vireo pusillus* *albatus*, the type locality of the new form being Pasadena, California.[1] I have seen no specimens from this precise locality, but I have a number from Riverside, which, as far as I can discern, are indistinguishable from the breeding birds obtained in the Cape Region by Mr. Frazar. My skins from Arizona and Oposura, Mexico, are, as a rule, somewhat deeper colored, with more greenish on the flanks, but these differences (they are the chief ones claimed by Mr. Grinnell) do not seem to me sufficiently pronounced or constant to warrant the formal separation of the birds in question. If they be recognized as distinct races, however, I feel very sure that the bird of the Cape Region should be referred to *albatus* and not, as Mr. Grinnell appears to think, to the typical form.

The Least Vireo is known to occur in the Cape Region only during autumn, winter, and spring. Mr. Belding characterizes it as rare, but Mr. Frazar's collection contains no less than fourteen specimens. Of these, two were killed at Triunfo on April 20 and 21 respectively; three at Santiago in the latter part of November; and the remaining nine at San José del Cabo at various dates between August 30 and November 11. Mr. Bryant "obtained specimens on Santa Margarita Island in winter, and found them in May at San Fernando; at Comondu in March; at San Benito in April, and at El Rosario, May 21, 1889." "Mr. Anthony found it common in willow thickets on the northwest coast up to 3,000 feet altitude. Nesting from 500 to 2,500 feet altitude" (Bryant); "quite common and evidently nesting in the mesquite thickets" about the mission at San Fernando,[2] and "very common all along the base of the mountain, but probably not reaching above the live oaks at 4500 feet," on San Pedro Martir.[3]

In California, the Least Vireo is a common summer resident to a little north of the latitude of San Francisco. It is also found in Arizona and is said to range throughout western Mexico, although my collectors have obtained it only at Oposura, in the province of Sonora.

Vireo vicinior Coues.

Gray Vireo.

Mr. Frazar killed a Gray Vireo at Triunfo the first week of April and another at San José del Cabo on November 10. These specimens are the only ones that have been thus far found in the Cape Region, but further to the northward in Lower California, Mr. Belding has "noted them from south of Campo, at an altitude of 3,000 feet in May, 1884; near San Rafael in May, 1885, and the mountains east of Ensenada in April, 1887."[4]

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[1] Condor, III. 1901, 187.

[2] Anthony, Auk, XII. 1895, 142.

[3] Anthony, Zoe, IV. 1893, 244.

[4] Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 308.

V. vicinior is a rare summer resident of San Diego and San Bernardino counties, California, but is not known to occur further northward on the Pacific coast. It is common in portions of Arizona and is also found in New Mexico and western Texas. I have only two specimens from western Mexico, both taken by Mr. Frazar at Guaymas in January, 1887.

Mniotilta varia (Linn.).

Black and White Warbler.

Mr. Frazar's collection contains a female Black and White Warbler, taken at Triunfo on December 20, 1887. This is the first known instance of the occurrence of the species in Lower California, and for the Pacific Coast district north of the Peninsula there are, I believe, but three records,[1] all of which relate to California. These four birds were, no doubt, chance wanderers from the regular path of migration which, in the United States, lies well to the eastward of the Rocky Mountains. The Black and White Creeper is common in Central America during winter, and it also passes into South America as far as Bogota and Venezuela.

Helminthophila celata (Say).

Orange-crowned Warbler.

(?) *Helminthophaga celata* Baird, Rev. Amer. Birds, pt. I. 1864, 1865, 176, 177 (San José; Cape St. Lucas).

Helminthophila celata Belding, Proc. U. S. Nat. Mus., V. 1883, 535 (Cape Region). Ridgway, *Ibid.* (crit.). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 308 (Cape Region).

According to Mr. Ridgway, an Orange-crowned Warbler (No. 86,272 U. S. Nat. Mus.) taken by Mr. Belding near La Paz in January, 1882, "appears to be referable to this form."

Mr. Frazar also obtained one (♀ No. 15,121, San José del Cabo, October 17, 1887) which is nearly or quite typical *celata*, while several others in his series are variously intermediate between *celata* and *lutescens*. The occurrence of true *celata* in the Cape Region is in no way surprising, for it breeds in the interior of Oregon and British Columbia and thence northward to Alaska. No doubt some of the birds which visit these regions in summer regularly pass through

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[1] Bryant, Proc. Calif. Acad. Sci., 2d ser., I. 1888, 48, "male in good plumage" found on South Farallone Island on May 28, 1887; Grinnell, Pub., II. Pasadena Acad. Sci., 1898, 44, immature female taken near Pasadena, Los Angeles county, on October 2, 1895; Emerson, Condor, III. 1901, 145, "male in fall plumage" obtained at Point Lobos, Monterey county on September 8, 1901.

Lower California on their way to and from western Mexico, where *celata* is common in spring and autumn. It is said to winter in southern Mexico, the extreme southern limit of its known range at that season being Guatemala.

Helminthophila celata lutescens (Ridgw.).

LUTESCENT WARBLER.

(?) *Helminthophaga celata* (not *Sylvia celata* Say) Baird, Rev. Amer. Birds, pt. I. 1864, 1865, 176, 177 (San José; Cape St. Lucas).
Helminthophila celata lutescens Belding, Proc. U. S. Nat. Mus., V. 1883, 536 (Cape Region); VI. 1883, 347 (Victoria Mts.). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 308 (Cape Region). Townsend, Proc. U. S. Nat. Mus., XIII. 1890, 137 (Cape St. Lucas).

This, the characteristic form of the Cape Region, is a rather common winter resident, arriving from the north early in October and departing again before the end of February, according to Mr. Frazar, who took no specimens later than February 9. He found the bird at La Paz, San José del Cabo, Santiago, Triunfo, and San José del Rancho, but not on the Sierra de la Laguna. Mr. Bryant records it from Santa Margarita Island (January), Comondu (March), San Benito Cañon (April 10), and El Rosario (May 21), while Mr. Anthony has met with it during the spring migration (in late April and early May) at San Fernando and about the base of San Pedro Martir.[1]

H. c. lutescens winters as far north as San Diego. Its summer range includes most of California and the regions northward to Alaska, chiefly on the Pacific slope. I have typical specimens from western Mexico.

Dendroica aestiva (Gmel.).

YELLOW WARBLER.

(?) *Dendroeca aestiva* Belding, Proc. U. S. Nat. Mus., V. 1883, 536, part (Cape Region).
(?) *Dendroica aestiva* Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 309, part (Cape Region).

All but one of the eleven Yellow Warblers obtained in the Cape Region by Mr. Frazar are young birds which were killed in autumn. The exception, a male taken at La Paz on February 5, is in nearly full nuptial condition. This bird seems to be *sonorana*, while four of the young females (from San José del Cabo) are quite typical of that race. The remaining six birds apparently belong to the form which breeds in California, and which, although usually called *aestiva*, has been referred by a few writers to *morcomi*.[2] It differs rather constantly from *aestiva* of eastern North America in having the chestnut streaks on the under parts narrower and fainter — in this respect showing an approach to *sonorana*, from which, however, it may be readily distinguished by the decidedly darker, greener coloring of its upper parts. The female is similar to *aestiva* (although less often streaked beneath) and hence quite different from that of *sonorana*, which is grayish above and clay-colored beneath, with but faint traces of yellowish on the body plumage. On the whole the Yellow Warbler of California seems to me too nearly like true *aestiva* to be recognized as a distinct subspecies. In any case it should not be called *morcomi*. At least Mr. Ridgway and I agree in considering the type of that supposed form merely an exceptionally faintly streaked specimen of *aestiva*, of which, moreover, the National Museum possesses a number of *perfectly typical* examples from the same general region (i. e. Utah and Montana) one of them being actually from the same locality (Fort Bridger).

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[1] Auk, XII. 1895, 142; Zoe, IV. 1893, 244.

[2] *Dendroica aestiva morcomi* Coale, Ridgway Orn. Club, Bull., II. 1887, 82.

Mr. Frazar found the Yellow Warbler rather rare in January and February at La Paz, where it frequented the shrubbery in the town gardens. It was not noted after March 1 (save on April 21, when one was seen at Triunfo) until August 28, when it was again met with at San José del Cabo. Here it became common by the latter part of September, but it kept so closely concealed in dense thickets as to be much oftener heard than seen. A single specimen was also taken at Santiago on November 16. To the northward of La Paz it does not seem to have been observed by any one except Mr. Anthony, who "says it is common on the northwest coast up to 2,500 feet altitude" (Bryant), and "common during migration in the valleys and as a summer resident in the higher altitudes," on San Pedro Martir.[1]

The Yellow Warbler breeds plentifully on the Pacific coast from southern California to Washington, being replaced in British Columbia and to the northward by the closely allied subspecies, *rubiginosa*. It is not known to occur north of the southern boundary of the United States during the winter months, when it migrates to Central America and the more northern portions of South America.

Dendroica aestiva sonorana Brewst.

Sonora Yellow Warbler

(?) *Dendroeca aestiva* Belding, Proc. U. S. Nat. Mus., V. 1883, 536, part (Cape Region).

(?) *Dendroica aestiva* Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 309, part (Cape Region).

Among the Yellow Warblers collected by Mr. Frazar there are, as I have just stated in another connection, four young females killed at San José del Cabo — on October 5, 12, 20, and 27 respectively — which are perfectly typical specimens of *sonorana*, besides a male in nearly full nuptial plumage obtained at La Paz on February 5, and also referable to this form, which has not been previously reported from anywhere on the Peninsula; nor does Mr. Belding include it in his Land Birds of the Pacific District, although it occurs, at least casually, in the extreme southern part of California, for I have a female (No. 6,349) taken by Mr. F. Stephens at Riverside on September 14, 1881. The true home of *sonorana* is, however, southern Arizona and western Mexico, the most southern locality from which I have received specimens being Alamos, Sonora.

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[1] Anthony, Zoe, IV. 1893, 244.

Dendroica aestiva rubiginosa (PALL.).

ALASKAN YELLOW WARBLER.

Dendroeca aestiva (not *Motacilla aestiva* GMELIN) BELDING, Proc. U. S. Nat. Mus., V. 1883, 536, part at least (Cape Region).

Dendroica aestiva (not *Motacilla aestiva* GMELIN) BRYANT, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 309, part at least (Cape Region).

Of this form of the Yellow Warbler, characterized by the nearly uniform dark olive green of the upper parts which almost completely overlies and obscures the yellow on the rump and crown, the National Museum collection possesses a perfectly typical female (No. 87,531) taken by Mr. Belding at San José del Cabo on April 17, 1882. This is the only specimen which I have seen from any part of Lower California. Mr. Nelson has recorded *rubiginosa* from as far south as the Tres Marias Islands, where it occurs, of course, only as a migratory visitor. According to its describer, Mr. Oberholser,[1] it breeds from British Columbia to Alaska.

Dendroica bryanti castaneiceps RIDGW.

MANGROVE WARBLER.

Dendroeca vieilloti bryanti (not of RIDGWAY, Amer. Nat., VII. 1873, 606) RIDGWAY, Proc. U. S. Nat. Mus., IV. 1882, 414, 415 (crit.; La Paz). BELDING, *Ibid.*, V. 1883, 536 (La Paz; Pichalinque Bay; Espiritu Island).

D.[*endroica*] *bryanti β. castaneiceps* RIDGWAY, *Loc. cit.*, VIII. 1885, 350 (orig. descr.; type from La Paz).

Dendroica bryanti castaneiceps RIDGWAY, *Loc. cit.*, footnote (name only). BRYANT, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 309 (La Paz; Pichalinque Bay; Espiritu Santo Island).

Two of the five males taken by Mr. Frazar agree closely with Mr. Ridgway's description of the type, and two disagree in having the breast and sides distinctly but finely streaked with chestnut rufous. The fifth (No. 15,087, La Paz, February 7, 1887), which probably represents some unusual if not abnormal phase of coloration, differs very decidedly from the others as well as from all the specimens mentioned by Mr. Ridgway. It has the head dull chestnut, very pale and mixed with whitish on the throat, mottled with greenish on the crown; the jugulum, sides of the neck and the middle of the breast *white* with occasional small patches or single feathers of a pale yellow color and numerous fine, chestnut-rufous streaks on the breast; the remainder of the under parts pale primrose yellow mixed with whitish. The back, wings, and tail are nearly as in the adult female. The upper mandible is of the usual dusky horn color, but the basal half of the lower mandible of a pale flesh color. The plumage, generally, has a worn and faded appearance.

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[1] Auk, XIV. 1897, 78.

One of the females in my series (No. 15,088, La Paz, March 21, 1887) has the yellow of the under parts dull gamboge; the crown and superciliary stripe tinged with rufous; the throat obscurely streaked with rufous chestnut. There are also a few nearly obsolete chestnut streaks on the breast.

In the winter and early spring of 1881–82 Mr. Belding found this beautiful Warbler "common in the shrubbery around the Bay of La Paz." It was "also seen at Pichalinque Bay and Espiritu Santo Island. It frequented almost exclusively the mangroves (*Rhizopora mangle*), and is probably resident." During January, February, and a part of March, 1887, Mr. Frazar repeatedly visited all the mangrove thickets that he could find near La Paz, and made every effort to secure a good series of these Warblers, but he took only eight in all and did not shoot more than a pair in any one day. He notes the bird as "rare," but adds that "its numbers increased slightly in March." It cannot be very numerous here at any time, for the total area covered by its favorite mangroves is very limited. Indeed, the place where most of his specimens were obtained "comprises only about two acres, through which winds a small creek, fordable at low tide; but at high water everything is submerged up to the lower branches of the mangroves. I always found the birds working near the surface of the water on the stems of the mangroves or hopping about on the mud, but the males resorted to the tops of the bushes to sing. Their notes are similar in general character to those of the Yellow Warbler."

Mr. Bryant heard the Mangrove Warbler singing "in the mangroves bordering the long *estero* northward from Magdalena Bay, and in the mangroves on Santa Margarita Island," where a male was seen by him on March 2, 1889. It is not unlikely that the localities just mentioned represent the extreme limit of northward distribution of this bird. Southward it is known to range as far as Mazatlan on the western coast of Mexico. On the Atlantic coast of Central America from Belize to Merida, Yucatan, it is replaced by the closely allied *D. bryanti*.

Dendroica auduboni (Towns.).

AUDUBON'S WARBLER.

Dendroica audubonii BAIRD, Rev. Amer. Birds, pt. I. 1865, 188, 189 (Cape St. Lucas).

Dendroeca auduboni BELDING, Proc. U. S. Nat. Mus., V. 1883, 536 (Cape Region); VI. 1883, 347 (Victoria Mts.).

Dendroica auduboni BRYANT, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 309 (Victoria Mts.; Cape Region).

Young females of this species in autumn plumage not infrequently lack all traces of yellow on the throat. In this condition, which is represented by several birds in Mr. Frazar's collection, they are not easily distinguishable from the young of *coronata*, although their upper parts are usually somewhat more ashy in tone, and their wings and tails longer. Even in these respects the two species occasionally resemble one another so closely as to render their discrimination a matter of no slight difficulty.

Audubon's Warbler appears to find only a winter home in the Cape Region, which it reaches rather late in autumn, judging by the experience of Mr. Frazar who first observed it at that season on November 9 at San José del Cabo. Later he found it common and universally distributed over the entire country, not less abundantly, indeed, on the summit of the Sierra de la Laguna than throughout the lowlands bordering the coast. At La Paz the last stragglers left for the north before the end of the first week of March.

Mr. Bryant records Audubon's Warbler from several places in the upper portions of the Peninsula, and Mr. Anthony reports that it is "very abundant during migrations" about San Pedro Martir, where, however, it is not known to breed, even on the summit of the elevated plateau.[1] It is resident in California, breeding in the mountains as far south as San Bernardino county, and also ranging in summer into British Columbia, but not, apparently, to Alaska, where it is replaced by *D. coronata*. Its southward migration extends to Guatemala.

Dendroica nigrescens (TOWNS.).

BLACK-THROATED GRAY WARBLER.

Dendroeca nigrescens BELDING, Proc. U. S Nat. Mus., VI., 1883, 347 (Victoria Mts.).

Dendroica nigrescens BRYANT, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 309 (Victoria Mts.).

This is another winter resident, less numerous and widely distributed than *D. auduboni*, but by no means uncommon in places suited to its tastes. Mr. Belding seems to have found it only on the mountains "above 3,000 feet altitude" and "in mountain cañons of about 1,000 feet altitude." Mr. Frazar's experience was essentially similar, although he took one specimen (perhaps a migrant) at La Paz on March 30. The species was rare at Triunfo in April, but common on the Sierra de la Laguna in the latter part of November, and at San José del Rancho in December. All of the ten specimens taken in autumn appear to be *old birds*. Mr. Frazar's latest spring date is April 27, when a female was shot on La Laguna.

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[1] Zoe, IV. 1893, 244.

Mr. Bryant took specimens at Tia Juana on May 2 and observed others at Hansen's on May 14. He states that "Mr. Anthony has found it only in the region of San Pedro Martir where it breeds from 7,500 to 11,000 feet altitude."

In California *D. nigrescens* occurs chiefly during migration, but it also breeds sparingly in the Sierras from San Bernardino county northward through Oregon and Washington into British Columbia. It is a common bird in western Mexico in autumn, winter, and early spring, but it has not been found south of the State of Oaxaca.

Dendroica townsendi (Towns.).

Townsend's Warbler.

Dendroeca townsendi Belding, Proc. U. S. Nat. Mus., V. 1883, 549 (Miraflores).
Dendroica townsendi Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 309 (Miraflores).

Mr. Belding's mention of a male seen at Miraflores, on April 4, 1882, is the only record for the Cape Region, but the same observer, according to Mr. Bryant, shot some specimens at Tia Juana on May 2, and "Mr. Anthony has taken a single bird in spring at San Quintin" (Bryant) and another on May 7 at San Fernando, while in 1893, in the region about San Pedro Martir, he saw a dozen or more in the live oaks in Burro Cañon on April 23, and a number of others at Valladares, and "on the west side of San Pedro" on May 3 and 4.[1]

Townsend's Warbler occurs regularly, and at times commonly, in California, at its seasons of migration, as well as occasionally in winter,[2] but it is not known to breed in this State, even among the higher mountains. Its summer range extends from Oregon and British Columbia to Alaska, where it is tolerably common at Glacier in the Yukon valley.[3] During spring and autumn it is apparently more numerously represented in the Rocky Mountains than near the Pacific coast, and in Mexico its principal path of migration evidently lies along the range of the Sierra Madres, for Mr. Frazar found it exceedingly abundant in the early autumn of 1888 in the more elevated parts of the province of Chihuahua. It is said to occur commonly in winter in Guatemala, south of which it has not as yet been found.

Seiurus noveboracensis notabilis (Ridgw.).

Grinnell's Water-Thrush.

Siurus naevius notabilis Belding, Proc. U. S. Nat. Mus., V. 1883, 536 (Cape Region). Ridgway, *Ibid.* (La Paz; crit.; measurements).
Seiurus noveboracensis notabilis Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 310 (La Paz; Todos Santos).

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[1] Zoe, IV. 1893, 244.

[2] Grinnell, Pub. II. Pasadena Acad. Sci., 1898, 46 (Los Angeles county).

[3] Bishop, N. Amer. Fauna, no. 19, 1900, 90.

Mr. Belding and Mr. Frazar agree in considering this a rare bird in the Cape Region. Mr. Frazar took only five specimens, two at La Paz on January 11, one at Triunfo on April 21, and two at San José del Cabo on September 12 and 22, respectively. At the place last named two others were seen, one on September 18, the other on October 4. Mr. Belding also obtained two at La Paz and, according to Mr. Bryant, a third at Todos Santos. The bird has not been reported from anywhere north of La Paz on the Peninsula, and only three specimens are known to have occurred in California, two at Santa Cruz, and one at San Diego. My Lower California examples appear to be typical representatives of *notabilis*. Only one of them is at all yellowish beneath, and in this the yellow is merely a faint tinge.

The summer range of *S. n. notabilis* has not been definitely traced, but it probably lies chiefly in the interior of western North America, north of the United States. Mr. Chapman has recorded[1] two specimens taken at Ducks, British Columbia, in August, but this date is not sufficiently early to prove that they were on their breeding-grounds. Mr. Nelson refers the form which occurs in Alaska to *noveboracensis*,[2] but Mr. Grinnell has since reported[3] that *notabilis* is moderately common in summer in the Kotzebue Sound Region, and Dr. Bishop has taken it in the Yukon valley.[4]

Geothlypis tolmiei (Towns.).

Macgillivray's Warbler.

Geothlypis macgillivrayi Baird, Rev. Amer. Birds, pt. I. 1865, 227 (Cape St. Lucas). Belding, Proc. U. S. Nat. Mus., V. 1883, 536 (Cape Region). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 310 (Cape Region).

G.[eothlypis] macgillivrayi Bryant, Zoe, II. 1891, 192 (San José del Cabo).

Mr. Belding found Macgillivray's Warbler only in "mountain cañons," and marks it "rare," but Mr. Frazar met with it in December at San José del Rancho, "where it is certainly a common winter resident." The latter observer's collection contains eight specimens taken in November at this place, five shot in November, and one on April 20, at Triunfo, one killed on November 15 at Santiago, and a bird obtained on February 16 at La Paz. Mr. Bryant records the species only from Tia Juana, where "it occurs as a migrant," and from Comondu, where a female was shot in March, 1888.

G. tolmiei is merely a migratory visitor to the southern part of California, but it breeds sparingly in the central and northern counties, chiefly in or near the mountains, and commonly in Oregon and northward into British Columbia. In winter it goes as far south as Panama.

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[1] Bull. Amer. Mus. Nat. Hist., III. 1890, 151.

[2] Rep. Nat. Hist. Coll. Alaska, 1887, 204.

[3] Pacif. Coast Avifauna, no. 1, 1900, 56, 57.

[4] N. Amer. Fauna, no. 19, 1900, 91.

Geothlypis trichas arizela OBERH.

OBERHOLSER'S YELLOW-THROAT.

Geothlypis trichas (not *Turdus trichas* LINNAEUS) BAIRD, Rev. Amer. Birds, pt. I. 1865, 220, 222, part (Cape St. Lucas). BELDING, Proc. U. S. Nat. Mus., V. 1883, 536 (Cape Region).

Geothlypis trichas occidentalis (not of BREWSTER), BRYANT, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 310 (Cape Region).

G.[eothlypis] trichas occidentalis (not of BREWSTER) BRYANT, Zoe, II. 1891, 192 (San José del Cabo).

Geothlypis trichas arizela OBERHOLSER, Auk, XVI. 1899, 256–258 (orig. descr.; type from Fort Steilacoom, Wash.; La Paz; San José del Cabo).

The large series of autumnal specimens of this form collected by Mr. Frazar[1] represents very fully the winter plumages of the adult and young of both sexes.

The adult male in autumn has the crown, nape, back, wing coverts, under tail coverts, and sides of body strongly tinged with cinnamon (nearly pure cinnamon brown on the crown and flanks); the black feathers of the mask tipped with grayish on the auriculars and sides of the neck, with mixed gray and cinnamon on the forehead;[2] in every other respect it is similar to the male in spring.

The young male in autumn differs from the adult at the same season in having the black of the mask restricted to a broad malar stripe and in possessing some concealed spotting at the base of the feathers of the forehead. The upper parts, also, show less cinnamon, and the entire top of the head is nearly concolor with the back. The yellow of the breast is sometimes tinged with saffron, but this is also the case with some apparently mature birds.

The adult female in autumn is rather more olivaceous above than are specimens of the same sex taken in spring, and the throat and breast are of a deep ochre yellow tinged with saffron. The forehead is suffused with cinnamon as in the spring female.

The young female in autumn has the entire under parts nearly uniform clayey buff, lightest on the middle of the abdomen, slightly brownish on the flanks. The upper parts are plain, dull, grayish olive, nearly uniform everywhere, but with a slight tinge of cinnamon on the forehead. In some specimens the breast is suffused with dull yellowish, but none show any yellow on the throat. The tint of the under parts varies considerably with different individuals, and there is often a trace of cinnamon on the flanks as well as, sometimes, on the breast. There is no difficulty whatever in separating *arizela*, in any of the plumages just described, from its eastern representative, *trichas*, the two appearing to differ quite as markedly in their immature or autumnal conditions as in full spring dress. I have not been able to make a satisfactory comparison of the autumnal or winter plumages of *arizela* with those of *occidentalis*, but breeding birds of these forms may be easily distinguished by the characters to which Mr. Oberholser has called attention.

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[1] It is possible that some of the immature Yellow-throats in this series are referable to *G. t. scirpicola*, while others may be *G. t. sinuosa*, but both these forms are said by their describer to be "permanently resident" in California (see Grinnell, Condor, III. 1901, 65).

[2] In a very few birds there is no trace of this light tipping, the mask being quite as pure black as in spring.

Mr. Frazar found this Yellow-throat in March at La Paz, where it was rare; in autumn at San José del Cabo, where it was exceedingly abundant; and at San José del Rancho (the only place not directly on the coast), where two specimens were obtained on December 22. At San José del Cabo it was present in small numbers at the date of Mr. Frazar's arrival, August 23, but it did not attain its maximum abundance until about the middle of September, after which its numbers steadily but gradually diminished, although it remained common throughout October, and indeed up to the time of Mr. Frazar's departure, November 13. It probably winters in the Cape Region, but there is no present evidence to show that it ever breeds there.

Throughout the central portions of the Peninsula Mr. Bryant has met with only a single specimen — on Santa Margarita Island. Mr. Anthony, however, found what was probably this subspecies, common "in swamps along the northwest coast" (Bryant), and a few were heard by him in the tules bordering a water hole at San Fernando while they were "not uncommon about the base" of San Pedro Martir in late April and early May.[1]

I have typical examples of *arizela* taken in winter and early spring at Guaymas and Oposura in northwestern Mexico. According to Mr. Grinnell,[2] this form "occurs abundantly in parts of California during the spring and fall migrations," and is found in the breeding season "on the Pacific slope from Central California to British Columbia," while a larger race — *scirpicola* — is "permanently resident in the fresh-water tule beds of the southern coast district," and a smaller one — *sinuosa* — similarly restricted at all seasons to the "salt marshes of San Francisco Bay and vicinity."

Of the value and constancy of the characters which are thought by Mr. Grinnell to distinguish *scirpicola* and *sinuosa* from each other — and from *arizela* — I have no present means of judging, but *arizela* is unquestionably a good subspecies.

Geothlypis beldingi Ridgw.

BELDING'S YELLOW-THROAT.

Geothlypis beldingi RIDGWAY, Proc. U. S. Nat. Mus., V. 1882, 344, 345 (orig. descr.; types from San José del Cabo); VI. 1883, 158, footnote (crit.; S. Lower Calif.) BELDING, *Ibid.*, V. 1883, 546 (San José; Miraflores; cañons of the

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[1] Auk, XII. 1895, 142; Zoe, IV. 1893, 245.

[2] Condor, III. 1901, 65.

Miraflores and Santiago Peaks; Agua Caliente). SHARPE, Cat. Birds Brit. Mus., X. 1885, 356, 357 (descr. ad. male from San José del Cabo). A. O. U., Check List, 1886, 315, no. 682. COUES, Key N. Amer. Birds, 4th ed., 1894, 870 (descr.; Lower Calif.). BRYANT, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 20–22 (descr. nest, eggs, and immature plumage from Comondu), 310–312 (quotes Belding as to locality; Comondu; n. to San Ignacio; descr. song; measurements). ALLEN, Auk, X. 1893, 142 (tropical type).

G.[eothlypis] beldingi BRYANT, Zoe, II. 1891, 192 (San José del Cabo). RIDGWAY, Man. N. Amer. Birds, 2d ed., 1896, 524 (descr.; s. portion of Lower Calif.).

[Geothlypis] beldingi DUBOIS, Synop. Avium, fasc. VI. 1901, 437 (Basse-Californie).

The large series of specimens obtained by Mr. Frazar probably illustrates every stage of plumage through which this beautiful species regularly passes. Three males, collected in April, agree closely with Mr. Ridgway's description of the specimens taken by Mr. Belding. A fourth, shot on June 20, at Triunfo, disagrees in having a poorly defined but nevertheless rather conspicuous yellow band across the fore part of the back. A female, taken on April 21, differs slightly from Mr. Ridgway's type in having a narrow but perfectly distinct yellowish superciliary stripe and a few dusky feathers in the malar region. The five birds just mentioned are all that Mr. Frazar secured in spring.

Age and seasonal variations: — Young in juvenal plumage. Female (No. 15,275, San José del Cabo, September 5, 1887). Above dull brownish drab, the wings faintly, the tail distinctly, tinged with olive; greater and middle wing coverts edged and tipped with rusty, forming obscure wing bands; below pale brownish buff, deepest on the sides, abdomen, and upper portion of the breast, unmixed with yellow save on the chin, where there are a few bright yellow feathers, evidently those of the first winter plumage; bend of wing slightly yellowish; under surface of wing ashy white; lores with a faint yellowish tinge.

Another specimen, apparently of about the same age, taken on September 12, is generally similar but rather browner above and on the breast and throat. A young male, obtained on August 23, differs from both of the specimens just described in having a few dark olive feathers on the back, a patch of bright yellow on the chin and upper part of the throat, a good many yellow feathers sprinkled over the breast, some black feathers in the lores, and a short black malar stripe. A careful examination of its plumage shows that all these olive, yellow, and black feathers belong to the first winter plumage, which was evidently just beginning to start when the bird was killed. Some of the feathers of the under parts, which appear to belong to the juvenal plumage, are, however, distinctly yellowish buff, as in the young bird described by Mr. Bryant.

Adult male in autumn. Differing from the spring male only in having the yellow of the crown paler and tinged with grayish white; the upper parts of a deeper, browner olive, tinged slightly on the occiput and nape with purplish brown; the yellow of the under parts richer with more decided brownish on the sides and flanks; the base of the lower mandible flesh colored; the remainder of the bill dark horn colored instead of black. The black mask is wholly unmixed with any lighter color.

Male in first winter plumage. Differing from the adult only in having the feathers of the black mask slightly tipped with grayish or yellowish, especially on the forehead; the yellow border of the mask more restricted and mixed with brownish; the breast and under tail coverts tinged with brownish saffron; the flanks and sides rich purplish cinnamon.

Adult female in autumn. Differing from the spring female only in being slightly grayer above.

Female in first winter plumage. Differing from the adult female in autumn only in having the upper parts tinged with reddish brown, the throat and breast with brownish saffron, the flanks and sides, as well as the anal region, with cinnamon.

Individual variations: — The width of the black mask where it crosses the forehead varies considerably in different specimens, being in some birds fully twice as wide as it is in others. There is quite as much diversity in this respect among young as with mature birds. One or two males have the entire occiput and nape mixed with concealed yellow. In about ten per cent of the autumnal males, both adults and young, the black of the forehead extends much further back on the left than on the right side of the head. In the most extreme specimens the posterior border of the black band crosses the top of the head obliquely, in a nearly straight line, from a little in front of the right eye to a little behind the left eye. In all cases, however, the black on the sides of the head passes completely around both eyes. At first I was inclined to believe that this remarkable variation was due to unevenness of manipulation on the part of the taxidermist in drawing the skin back over the skull, but careful examination of numerous specimens has convinced me, as well as several others who have looked at the birds, that they present a clear and very interesting case of asymmetry.

This beautiful species was discovered by Mr. Belding (in 1882) in the Cape Region, where it was "common in the few suitable localities around San José, Miraflores, and cañons of the Miraflores and Santiago Peaks. At Agua Caliente a pair were noticed feeding their young just out of the nest, May 7. The only note traced to this species was a loud *chip*. . . . Their habits are quite like those of *G. trichas*, and the eggs are not materially different, if a nest found by my guide on the Miraflores and Todos Santos trail May 6 belonged to this species, as I supposed it did, having seen a fine male near the spot from which it was taken."

Mr. Frazar saw his first Belding's Yellow-throat on April 21 at Triunfo, in a small, deep arroyo where the stream had been dammed for irrigating purposes, making a little pool of water around which grew a quantity of canes and rank grasses, the whole covering an area of about forty yards square. Here were found three pairs, the females of which were apparently incubating, although no nests were discovered. The species was next met with at San José del Cabo, where it proved to be one of the most abundant birds. It was also very common about the lagoon at Santiago, frequenting rushes, often where the water was three or four feet deep, in this respect differing from Oberholser's Yellow-throat which inhabited thickets of bushes growing on comparatively dry ground. "The song resembles that of the Maryland Yellow-throat, but is so much heavier and fuller that it can be easily recognized." The bird occasionally mounts into the air and sings on wing. Mr. Frazar noticed that the Belding's Yellow-throats diminished sensibly in numbers at the approach of winter, and he is of the opinion that many migrate southward at that season, but this seems improbable, inasmuch as the species has never been detected outside of Lower California.

It is not confined to the Cape Region, however, for Mr. Bryant has found it "on the west coast of lower Purisima cañon, and as far north as San Ignacio." In March, 1888, and April, 1889, it was also met with on the eastern side of the Peninsula at Comondu. Here "the birds kept mainly within the bulrushes and bushes of the creek, but could be called out by imitating the cries of a bird in distress. I frequently heard them singing, sometimes in the top of a low tree. Their notes are rather loud and quite clear, an interval of a few seconds occurring between each song." Mr Bryant describes the song as follows, the stars representing "a low, short buzz." "*Sweet, sweet* * * * *ear* * * * *sweet, sweet ear* * * * *sweet, sweet ear*," or "*sweet, sweet ear* * * * *sweet, sweet ear*," or "*sweet, sweet ear* * * * *sweet, sweet ear* * * *," all three forms being used by the same individual bird.

A nest found at Comondu on March 25, 1889, by Mr. T. S. Brandegee while in company with Mr. Bryant, "was loosely woven in a clump of 'cat-tails,' . . . and thinly lined with fine fiber and a few horsehairs. It measures externally (as nearly as can be determined from its rough shape) not less than 150 mm. in height by about 115 mm. in diameter. The receptacle is about 55 mm. in depth, with a diameter at the top of 50 mm. The general appearance is almost identical with some song sparrows' nests."

The four eggs contained in this nest are larger than those of "any other North American yellow-throat, measuring 19 × 15; 19.5 × 15; 19.5 × 14.5; 19.5 × 14.5 millimetres. They are white, with shell spots and dots of lilac-gray and a few surface spots and pencillings of black." Four other nests and seven additional eggs taken by Mr. Bryant at this place are essentially similar to the specimens just described. All the nests, apparently, were in cat-tails. The female of one, when started off her eggs, "quietly retreated amongst the rushes and made no demonstration, further than a coarse 'tchep' note."

Icteria virens longicauda (Lawr.).

Long-tailed Chat.

Icteria virens Baird, Rev. Amer. Birds, pt. I. 1865, 229, part (descr. young birds from Cape St. Lucas).

Icteria virens longicauda Belding, Proc. U. S. Nat. Mus., V. 1883, 537 (Cape Region). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 312 (Cape Region).

Mr. Frazar met with the Long-tailed Chat only at San José del Cabo, where eight specimens were taken at various dates between September 15 and October 25. Mr. Belding notes it as rare, without mentioning just when or where he found it. Mr. Bryant says that it is common at Comondu "nesting in the bushes of the creek." The Mexicans call it the "'arriero' from the resemblance of its whistle to that made by a mule driver." Mr. Anthony considers it "common in the lower valleys" about San Pedro Martir, but it was "only seen occasionally along the base of the mountain."[1] In summer it ranges as far north as Oregon, breeding rather freely throughout most of California, and in winter it is not uncommon in western Mexico.

Wilsonia pusilla pileolata (Pall.).

Pileolated Warbler.

Myiodioctes pusillus pileolatus Ridgway, Proc. U. S. Nat. Mus, V. 1883, 533, foot-note (Agua Escandida; Sierra San Gertrude). Belding, *Ibid.*, VI. 1883, 350 (La Paz and s.).

Sylvania pusilla pileolata Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 313 (Cape Region); Zoe, II. 1891, 188 (San José del Cabo).

Mr. Belding gives this species as rare, but states that it was observed at several places in the lowlands about La Paz and southward. Mr. Frazar took only two specimens at La Paz, the first on February 5, the second on March 21. On the Sierra de la Laguna he shot a female on May 4, and a male on May 31. After this none were seen until August 25, when a specimen was taken at San José del Cabo. Here the bird soon became common, its numbers increasing steadily up to the middle of October after which they diminished rapidly. This, with the fact that only one or two were seen at San José del Rancho in December, led Mr. Frazar to conclude that the majority pass to the southward of the Cape before winter sets in. Mr. Bryant "found a few at Comondu in March, before the migration northward had ended." Mr. Anthony states that about the middle of May, 1893, "before we left the pine belt" on San Pedro Martir, "this warbler had become common along the streams; more abundant, however, in the lower valleys during migrations."[2] Aside from this statement there is no present evidence to indicate that the Pileolated Warbler breeds anywhere on the Peninsula, but it is a rather common summer resident of most parts of California and northward, along or near the coast, into Alaska. It migrates southward as far as Costa Rica and Panama.

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[1] Zoe, IV. 1893, 245.

[2] *Ibid.*

Setophaga ruticilla (Linn.).

American Redstart.

Setophaga ruticilla Belding, Proc. U. S. Nat. Mus., VI. 1883, 350 (Miraflores; ? La Paz). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 313 (Miraflores).

A female Redstart shot by Mr. Belding at Miraflores on February 24, 1883, is the only specimen known to have been taken in Lower California, although Mr. Belding thinks that he saw another at La Paz in March. The species has been found but twice in California, at Hayward's on June 20, 1881, by Mr. W. O. Emerson, and at Marysville Buttes on June 6, 1884, by Mr. Belding. It is probably merely a chance straggler to the Pacific coast of Upper and Lower California, although in British Columbia it is "found throughout the southern portions of the Province, and through the interior as far as Barkerville," but nowhere very commonly.[1]

The winter home of the Redstart includes western Mexico and the whole of Central America with northern South America to about the line of the Equator.

Motacilla ocularis Swinh.

Swinhoe's Wagtail.

Motacilla ocularis Ridgway, Proc. U. S. Nat. Mus., IV. 1882, 414 (crit.; La Paz); VI. 1883, 158 footnote (crit.; S. Lower Calif.). Belding, *Ibid.*, V. 1883, 535 (La Paz). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 313 (La Paz).

An "adult specimen in winter plumage" of this east Asiatic species was taken by Mr. Belding at La Paz on "January 9, 1882, during a cold gale from the north. It was found on a drift of sea-weed on the beach." This bird was doubtless a mere waif which had either wandered across the Pacific Ocean or had crossed Bering Strait and thence followed the coastline southward.

M. ocularis has been repeatedly noted at Plover Bay, Siberia, and it probably visits Alaska more or less frequently and regularly, although the only really valid record of its occurrence in any part of North America, other than that furnished by Mr. Belding's specimen, is the mention in the Catalogue of the Birds in the British Museum[2] of a young bird in the collection of that institution which was obtained in "N. W. America" by Captain Kellett and Lieutenant Wood.

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[1] Fannin, Check List Birds British Columbia, 1891, 42.

[2] Sharpe, Cat. Birds Brit. Mus., X. 1885, 473.

Anthus pensilvanicus (Lath.).

American Pipit. Titlark.

Anthus ludovicianus Baird, Rev. Amer. Birds, pt. I. 1864, 155 (Cape St. Lucas). Belding, Proc. U. S. Nat. Mus., V. 1883, 546 (San José del Cabo); VI. 1883, 347 (Laguna).

Anthus pensilvanicus Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 313 (San José del Cabo).

Mr. Frazar obtained a large number of Titlarks, all of which are in autumn plumage. Compared with specimens taken at corresponding seasons in the eastern United States they prove to be somewhat grayer above and paler (creamy instead of brownish buff) beneath, with smaller, more sharply defined spots on the breast and lighter, more conspicuous wing bands. These differences, however, are neither pronounced nor constant.

The Titlark is a common winter resident of the Cape Region, where, however, it appears to be chiefly confined to the neighborhood of the sea-coast. Mr. Frazar found it in February near La Paz; on March 13 at Loreto (opposite Carmen Island); and very numerously the following autumn (for the first time on October 4) at San José del Cabo, where, according to Mr. Belding, a few lingered "until about May 3, or later," in the spring of 1882. The latter observer also saw a large flock of birds which he took to be of this species on the Sierra de la Laguna, but none were met with there by Mr. Frazar.

Mr. Bryant collected moulting specimens of the Titlark at Comondu in April, and still further to the northward Mr. Anthony found it "abundant along the coast in winter," but about San Pedrŏ Martir only a few birds were "seen in May, 1889, on the eastern edge of the mountain."[1]

The Titlark is abundant in winter throughout California, but it is not known to breed in this State, nor indeed anywhere near the Pacific coast to the southward of Alaska. It migrates as far south as Guatemala.

Anthus cervinus (Pall.).

Red-throated Pipit.

Anthus cervinus Ridgway, Proc. U. S. Nat. Mus., VI. 1883, 156, 157 (San José del Cabo; descr. summer and winter plumage), 158, footnote (crit.; S. Lower Calif.). Belding, *Ibid.*, 350 (San José del Cabo). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 313 (San José del Cabo).

This is another chance straggler to Lower California for which a single adult bird in winter plumage, taken by Mr. Belding at San José del Cabo on January 26, 1883, furnishes the sole record. Besides this specimen there is known to be but one other — also in the collection of the National Museum — which was taken in North America, at St. Michael's, Alaska, by Dr. Dall, during the Russian Telegraph Expedition. The species is normally confined to the Old World, where it has an extensive range, being found throughout Europe, in northern Africa, and in Asia from northern Siberia to Japan, China, and India.

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[1] Zoe, IV. 1893, 245.

Oroscoptes montanus (Towns.).

Sage Thrasher.

Oreoscoptes montanus Belding, Proc. U. S. Nat. Mus., V. 1883, 534 (Cape Region).

Oroscoptes montanus Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 313, 314 (Cape Region).

Mr. Belding notes the Sage Thrasher as rare in the Cape Region. He does not state just when or where he found it, but the collection of the National Museum contains two specimens (No. 86,233, ♂, and No. 86,234, ♀), taken by him at La Paz on January 27, 1882. Mr. Frazar is very sure that he saw one on the road between San José del Cabo and Miraflores on November 18, 1887, but, with this possible exception, he did not meet with the species, nor has it been detected further to the northward by Mr. Bryant. Mr. Anthony, however, attests its presence "along the northwest coast in spring under 1,000 feet altitude" (Bryant), and also reports that it "winters in comparative abundance" throughout most of the region about San Fernando.[1]

The birds obtained at La Paz by Mr. Belding are larger and much deeper colored than any of my Texas skins, but they are closely matched by several specimens in my collection from Riverside, California.

The Sage Thrasher ranges northward, on or near the Pacific coast, to British Columbia, but does not appear to be common at many places west of the Sierras. I have several specimens from the city of Chihuahua, but none from the western part of Mexico.

Mimus polyglottos leucopterus (Vigors).

Western Mockingbird.

Mimus polyglottus (not *Turdus polyglottos* Linnaeus) Baird, Proc. Acad. Nat. Sci. Phila., 1859, 301 (Cape St. Lucas), 303 (crit.; Cape St. Lucas). Salvin and Godman, Biol. Centr.-Amer., Aves, I. 1879, 36, part (crit.; Cape St. Lucas). Belding, Proc. U. S. Nat. Mus., V. 1883, 534 (Cape Region); VI. 1883, 345 (Cape Region).

Mimus polyglottos (not *Turdus polyglottos* Linnaeus) Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 314 (Cape Region).

Mimus polyglottos leucopterus Mearns, Auk, XIX. 1902, 70–72 (orig. descr.; characters drawn from Lower California and other material).

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[1] Anthony, Auk, XII. 1895, 142.

As Dr. Mearns has recently pointed out, *Mimus polyglottos leucopterus* is an excellent subspecies, differing very appreciably, as well as constantly, from true *polyglottos* in having the general coloring of the upper parts less grayish (more drab); the under parts whiter posteriorly, and more strongly tinged with clay color on the throat and breast; the white markings on the wings much more extended and conspicuous; the general size larger, but the tail relatively shorter. In respect to all these characters the numerous specimens obtained in the Cape Region by Mr. Frazar are apparently typical of *leucopterus*. Professor Baird thought that the birds of this region have shorter tails than those found in California, but I find the reverse to be the rule, although the difference is neither marked nor constant.

The Western Mockingbird occurs throughout Lower California, and is probably resident wherever found. Mr. Belding characterizes it as "abundant" in the Cape Region. Mr. Frazar's experience does not corroborate this, for he says: "While most numerously represented at San José del Cabo, it cannot be called a common bird either there or about La Paz, and at Triunfo I found it rather rare. It is very generally distributed over the low country, but it was not seen by me at all on the higher mountains."

Mr. Bryant affirms that this Mockingbird is "everywhere common" on the portions of the Peninsula which he visited. It is not known to occur north of California, and in that State is found regularly and commonly only in the central and southern portions. It inhabits nearly the whole of Mexico, excepting the higher mountain regions, as far south as the Isthmus of Tehuantepec.

Toxostoma cinereum (Xantus).

St. Lucas Thrasher.

Harporhynchus cinereus Xantus, Proc. Acad. Nat. Sci. Phila., 1859, 298 (orig. descr.; type from Cape St. Lucas). Baird, *Ibid.*, 301 (Cape St. Lucas), 303 (crit.; Cape St. Lucas); Rev. Amer. Birds, pt. I. 1864, 46, 47 (descr.; Cape St. Lucas). Sclater, Cat. Amer. Birds, 1862, 8 (Lower Calif.). Elliot, Illustr. New and Unfig. N. Amer. Birds, I. 1869, pl. 1 (descr.). Cooper, Orn. Cal., 1870, 19 (descr.; figures head; Cape St. Lucas). Coues, Check List, 1873, 7, no. 12; 2d ed., 1882, 25, no. 22; Birds Col. Valley, 1878, 68, 69, fig. 11 (descr.; crit.). Baird, Brewer, and Ridgway, Hist. N. Amer. Birds, I. 1874, 40, 41, pl. 4, fig. 2 (descr. bird, nest, eggs, and habits; crit.). Sharpe, Cat. Birds Brit. Mus., VI. 1881, 355, 356 (descr.; La Paz). Ridgway, Nom. N. Amer. Birds (Bull. U. S. Nat. Mus., no. 21), 1881, 12, 60, 74, no. 14. Belding, Proc. U. S. Nat. Mus., VI. 1883, 345 (Cape Region). A. O. U., Check List, 1886, 324, no. 709. Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 314 (Cape Region; Comondu to San Quintin). Townsend, Proc. U. S. Nat. Mus., XIII. 1890, 136 (Cape St. Lucas). Allen, Auk, X. 1893, 142 (tropical type).

[*Mimus*] *cinereus* Gray, Hand-list, I. 1869, 263, no. 3,850.

[*Harporhynchus*] *cinereus* COUES, Key N. Amer. Birds, 1872, 75 (descr.; Cape St. Lucas). DUBOIS, Synop. Avium, fasc. VI. 1901, 417 (Basse-Californie).

H.[*arporhynchus*] *cinereus* COUES, Amer. Nat., VII. 1873, 327, 330, 331, fig. 70 (descr.; crit.); Key N. Amer. Birds, 4th ed., 1894, 253 (descr.; Lower Calif.). BELDING, Proc. U. S. Nat. Mus., VI. 1883, 344 (Lower Calif.). RIDGWAY, Man. N. Amer. Birds, 2d ed., 1896, 544 (descr.; Lower Calif.).

Hyporhynchus cinereus (err. typ.) JASPER, Birds. N. Amer. 1878, 151, pl. 103, fig. 6 (Cape St. Lucas).

Methriopterus cinereus BELDING, Proc. U. S. Nat. Mus., V. 1883, 534 (Cape Region). RIDGWAY, *Ibid.*, VI. 1883, 158, footnote (crit.; S. Lower Calif.).

Toxostoma cinerea RICHMOND, Auk, XIX. 1902, 89 (synonymy).

Toxostoma cinereum A. O. U. COMM., Auk, XIX. 1902, 328, no. 709.

Juvenal plumage: — (Female, No. 14,572, collection of William Brewster, San José del Rancho, July 6, 1887). Above ash brown strongly tinged with rusty, the hind back, rump, and upper tail coverts nearly pure rusty; wings and tail as in the adult, but with all the tail feathers tipped with rusty, the secondaries and greater and middle wing coverts tipped and edged with rusty fulvous, the primaries with rusty white; beneath rusty white, the rusty tinge deepest on the abdomen, crissum, and under tail coverts, the entire under parts, including the chin and abdomen — but not the middle of the throat, anal region, and under tail coverts — thickly spotted with clove brown, these spots largest across the breast, but everywhere much narrower and more numerous than in old birds.

Sexual variation: — The sexes do not seem to differ in size, color, or markings.

Seasonal variations: — Autumn birds are much more ashy above and buffy beneath than spring specimens. In some of the former, the wing coverts are tipped with rusty, and the flanks, abdomen, crissum, and under tail coverts with light rusty ochraceous. As the season advances, these colors gradually fade, until by April the upper parts become dull ashy brown, while the abdomen and crissum are only faintly tinged with rusty. In June the plumage is excessively worn and faded, and the under parts are essentially uniform soiled white.

Individual variations: — There is much diversity with respect to the spotting of the under parts. In the lighter colored birds the spots are small, rounded, and confined to the breast and the sides of the throat and body. The darker ones have the entire under parts — excepting the under tail coverts, crissum, anal region, and a small space on the middle of the throat and abdomen, which are always plain — thickly and coarsely marked with deltoid spots which, on the breast, are sometimes so large and numerous as to be almost confluent. In especially dark specimens the jugulum is usually densely but always finely spotted, and there are often a few fine markings on the chin. The whitish spots on the tail are ordinarily broad and conspicuous on the inner webs of the outer three feathers, extending .50 to .65 of an inch back from their tips, but in a few specimens they are restricted and, indeed, almost obsolete, being merely indicated by small spaces of brownish or rusty white, confined to the extreme ends of the feathers.

The bill of this species is subject to considerable variation in size and proportions, but its shape is fairly uniform.

My series furnishes no evidence indicating that this Thrasher ever grades into *T. bendirei.*

The St. Lucas Thrasher is confined to Lower California. It is resident and rather generally distributed in the Cape Region, where, however, it does not seem to occur at elevations much exceeding 3,000 feet. Mr. Frazar found it common in the neighborhood of La Paz and San José del Rancho, somewhat less numerous at Triunfo, and "very scarce" at San José del Cabo.

Mr. Bryant says that he met with it "throughout the overland route from Comondu to San Quintin," but this was before *T. c. mearnsi* had been described by Mr. Anthony, who states that his bird (which is decidedly darker and more rusty colored than true *cinereum*) "is quite common about San Quintin [the type locality], and in all suitable places as far south as I have collected." From this we may infer that all the more northern portions of the general range attributed to *cinereum* by Mr. Bryant are occupied by *mearnsi*, but as to just where the two birds meet and intergrade we are left in complete ignorance.

Dr. Brewer states that Xantus found St. Lucas Thrashers with full-fledged young as early as April 4, the date of his arrival at Cape St. Lucas, and that they "continued to breed until the middle of July." The nests which he took were "flat structures, having only a very slight depression in or near their centre." They were built in "low trees, shrubs, and most usually, cactus plants, and in no instance at a greater elevation from the ground than four feet. . . . The eggs vary somewhat in their ground color, but exhibit only slight variations in size or shape. Their greatest length is 1.13 inches, and their average 1.12 inches. Their mean breadth is .77 inch, and their maximum .79 inch. The ground color is a greenish-white, profusely marked with spots of mingled purple and brown. In others the ground color is a bluish-green. In some specimens the spots are of a yellowish-brown, and in some the markings are much lighter."

Three eggs in my collection, constituting a set taken at Cape St. Lucas on May 30, 1896, by Messrs. Coolidge and Miller, measure respectively: 1.04 × .79, 1.06 × .81, and 1.07 × .80. They are dull bluish white, with numerous and very generally distributed markings of pale lavender and light reddish brown.

Heleodytes brunneicapillus affinis (XANTUS).

ST. LUCAS CACTUS WREN.

Campylorhynchus affinis XANTUS, Proc. Acad. Nat. Sci. Phila., 1859, 298 (orig. descr.; type from Cape St. Lucas). BAIRD, *Ibid.*, 301 (Cape St. Lucas), 303, 304 (crit.; Cape St. Lucas); Rev. Amer. Birds, pt. I. 1864, 98, 100, 101 (descr.;

[1] Auk, XII. 1895, 52, 53.

crit.; Cape St. Lucas). SCLATER, Cat. Amer. Birds, 1862, 17 (Lower Calif.). ELLIOT, Illustr. New and Unfig. N. Amer. Birds, I. 1869, pl. 4 (quotes orig. descr.). COOPER, Orn. Cal., 1870, 62, 63 (descr.; crit.; Cape St. Lucas). COUES, Check List, 1873, 13, no. 44; 2d ed., 1882, 30, no. 64. BAIRD, BREWER, and RIDGWAY, Hist. N. Amer. Birds, I. 1874, 133, 134, pl. 8, fig. 6 (descr. bird, nest, and eggs; crit.; Cape St. Lucas). JASPER, Birds N. Amer., 1878, 151, pl. 103, fig. 8 (Cape St. Lucas). RIDGWAY, Nom. N. Amer. Birds (Bull. U. S. Nat. Mus., no. 21), 1881, 14, 61, 74, no. 57; Proc. U. S. Nat. Mus., VI. 1883, 158, footnote (crit.; S. Lower Calif.). BELDING, *Ibid.*, V. 1883, 535 (Cape Region); VI. 1883, 345 (Cape Region). A. O. U., Check List, 1886, 325, no. 714. BRYANT, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 315 (Cape Region; San Quintin and s.); Zoe, II. 1891, 188 (San José del Cabo). TOWNSEND, Proc. U. S. Nat. Mus., XIII. 1890, 136 (Cape St. Lucas). ALLEN, Auk, X. 1893, 142 (tropical type). ANTHONY, Zoe, IV. 1893, 245 (San Pedro Martir).

[*Campylorhynchus*] *affinis* GRAY, Hand-list, I. 1869, 192, no. 2,652. COUES, Key N. Amer. Birds, 1872, 85 (descr.; Cape St. Lucas).

C.[*ampylorhynchus*] *affinis* COUES, Birds Col. Valley, 1878, 157 (crit.); Key N. Amer. Birds, 4th ed., 1894, 275 (descr.; Lower Calif.). BELDING, Proc. U. S. Nat. Mus., VI. 1883, 344 (Lower Calif.).

Campylorhynchus brunneicapillus (not of LAFRESNAYE) SHARPE, Cat. Birds Brit. Mus., VI. 1881, 197, 198 (descr.; La Paz).

Heleodytes affinis A. O. U. COMM., Auk, XI. 1894, 48, no. 714. ANTHONY, *Ibid.*, 210–214 (crit.); XII. 1895, 280 (status).

H.[*eleodytes*] *affinis* RIDGWAY, Man. N. Amer. Birds, 2d ed., 1896, 547 (s. portion of Lower Calif.).

Heleodytes brunneicapillus affinis A. O. U. COMM., Auk, XIV. 1897, 131, no. 713 b.

[*Campylorhynchus*] *brunneicapillus* DUBOIS, Synop. Avium, fasc. VI. 1901, 420, part (Basse-Californie).

Sexual variations: — The sexes apparently differ only in respect to size, the females being usually, but not invariably, smaller than the males.

Seasonal variations: — Young in juvenal plumage differ from old birds in breeding plumage only in having the crown of a darker, duller brown (almost slaty brown in some specimens); the light markings of the back rusty white and broader, on many of the feathers taking the form of deltoid spots; the light markings of the wings, including those of the outer primaries (but not of the tail), strongly rusty; the spotting of the under parts finer and somewhat fainter.

Young (and perhaps old birds also) in autumn differ from spring adults and young in juvenal plumage in having the light streaks of the back broader and whiter; the flanks, abdomen, anal region, and crissum bright cinnamon or ochraceous buff, instead of rusty white.

Individual variation: — Baird remarked[1] "a tendency to a whitish spotting in the ends of the feathers of the cap," which he regarded as characteristic of immature birds, but in the large series before me it occurs quite as frequently with apparently mature specimens taken in spring as with young in autumn, while it is not present in any of the young in juvenal plumage. Moreover, these crown spots are not "whitish" in any of my specimens, but always more or less rusty and often deep golden brown.

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[1] Rev. Amer. Birds, pt. I. 1864, 100.

In respect to the size, shape, and distribution of the dark markings of the under parts, there is quite as much variation as in most conspicuously spotted birds. Some of the more heavily marked specimens, especially the autumnal ones with rich buffy abdomens and flanks, resemble the lighter colored examples of *brunneicapillus* very closely, but the difference in the tail markings of the two species is so pronounced and constant that it can be relied upon to separate birds of any age or plumage. I have had no opportunity, however, of testing the characters by which the form *bryanti* is said to be distinguishable from *affinis.*

In the Cape Region proper the St. Lucas Cactus Wren is everywhere a common resident excepting on the higher mountains, where it appears to be wholly wanting. Its favorite haunts are the arid, cactus-grown plains near the coast and the almost equally barren and waterless foot-hills, but at San José del Cabo Mr. Frazar found it abundant in gardens and among shrubbery near or even directly over water. At this place birds were seen carrying sticks in their bills, apparently for the purpose of nest-building, as late as October 18, and the same thing was observed at Santiago about the middle of November. The sexual organs of the specimens killed at this time did not indicate, however, that any of them were breeding or about to breed.

Until somewhat recently the St. Lucas Wren was supposed to be confined to the Cape Region, but in 1888 and 1889 Mr. Bryant ascertained that it is also very generally distributed throughout the central portion of the Peninsula. Indeed he has reported its occurrence as far to the northward as San Quintin, but the birds of that locality have been since referred by Mr. Anthony to the closely allied *H. b. bryanti*, which is said to be easily distinguishable from both *brunneicapillus* and *affinis* by the exceptionally heavy dark markings on its under parts, but which, in other respects, is "practically intermediate" between these forms.[1] Mr. Anthony thinks that *bryanti* will be found to grade into *affinis* "at a point at no great distance south of San Fernando,"[2] and his material apparently establishes its complete intergradation with *brunneicapillus* in the more eastern parts of southern California.

Salpinctes obsoletus (Say).

Rock Wren.

Salpinctes obsoletus Baird, Rev. Amer. Birds, pt. I. 1864, 110 (crit.; Cape St. Lucas). Salvin and Godman, Biol. Centr.-Amer., Aves, I. 1880, 71 (Cape St. Lucas). Belding, Proc. U. S. Nat. Mus., V. 1883, 535 (Cape Region). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 315 (Cape Region).

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[1] Anthony, XI. 1894, 212.

[2] Auk, XII. 1895, 280.

Mr. Belding considers this species "not rare" in the Cape Region, but Mr. Frazar saw only a single pair during his stay there. They were in the graveyard at La Paz, and when first observed (on March 19) were engaged in building a nest. Three days later the male was secured. It does not differ in any way from examples in my collection from Colorado.

Mr. Bryant found a few Rock Wrens "on Santa Margarita and Magdalena Islands, and at various localities northward," while Mr. Anthony states that the species is "not uncommon in winter" at San Fernando,[1] and that at San Pedro Martir he found it nesting, in a single instance, "at 8500 feet; more common on the lower slopes."[2]

It occurs more or less numerously throughout California and northward into British Columbia, and is common and very generally distributed in central and western Mexico, where it breeds at every altitude from the crest of the Sierra Madre range to the low country near the Pacific coast. It ranges still further southward, to Guatemala and San Salvador.

Catherpes mexicanus punctulatus Ridgw.

Dotted Cañon Wren.

Catherpes mexicanus conspersus (not of Ridgway) Belding, Proc. U. S. Nat. Mus., V. 1883, 535 (Cape Region); VI. 1883, 347 (Victoria Mts.).

Catherpes mexicanus punctulatus Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 315 (Cape Region).

With this Wren, also, Mr. Belding and Mr. Frazar seem to have had somewhat diverse experiences. The former notes it as "moderately common throughout all altitudes," whereas the latter found it only on the Sierra de la Laguna. "There were a few here on my arrival (April 26) and their numbers increased steadily up to the date of my departure (June 9), but even then they had not become really common. I usually found them in cañons, but sometimes on hillsides where there were large boulders." There can be little doubt that they breed on this mountain, although Mr. Frazar obtained no definite proof that such is the case. Mr. Bryant secured "a male and four fledged young at San Sebastian," on April 28, 1889, and speaks of hearing old birds "far up the sides of the rocky walls that inclose Comondu." Mr. Anthony reports that the species was "not uncommon in several places on San Pedro" Martir in late April and early May, 1893,[3] and that he has also seen it in small numbers near San Fernando.[4] Upon comparing Mr. Frazar's specimens with the type of *C. m. punctulatus*, I find that they agree with it in all essential respects.

The Dotted Cañon Wren is rather generally distributed throughout California, but is not known to range further northward. It is also found in Arizona and New Mexico, and southward into Sonora and Chihuahua, Mexico.

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[1] Auk, XII. 1895, 143.

[2] Zoe, IV. 1893, 245.

[3] Zoe, IV. 1893, 245.

[4] Auk, XII. 1895, 143.

Troglodytes aëdon aztecus Baird.

Western House Wren.

Troglodytes aëdon parkmanni (not *Troglodytes parkmanii* Audubon) Belding, Proc. U. S. Nat. Mus., V. 1883, 535 (Cape Region).

Troglodytes aëdon parkmanii (not *Troglodytes parkmanii* Audubon) Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 316 (La Paz).

Parkman's Wren is included without comment by Mr. Belding in his list of birds "common to most or all of the localities where collections were made" "near the southern extremity of the Peninsula." Mr. Bryant also gives it as a bird of Lower California, but apparently solely on the authority of Mr. Belding, who, he states, "found it to be rare on Cerros Island, and collected a specimen at La Paz." Mr. Anthony mentions only *T. a. aztecus*, which, he says, was "abundant in the pines" on San Pedro Martir in late April and early May, 1893.[1]

Mr. Frazar's collection contains five House Wrens, of which two were taken at San José del Cabo on September 29 and October 17, respectively, one at Triunfo on December 9, and two at San José del Rancho on December 20 and 21, respectively. All of these birds seem to me to be referable to *aztecus*. They are certainly quite as ashy as average examples of that form, although in respect to the nearly obsolete character of the barring on the upper parts, they agree rather better with *parkmanii*.

From this it will appear that the status of the House Wrens which occur in the Cape Region in autumn and winter is still open to doubt. It is quite possible, of course, that some of them are really examples of *parkmanii* which migrate southward from California, but more probable, in my opinion, that most if not all of them are representatives (not quite typical, perhaps) of *aztecus*, which pass their summers at San Pedro Martir and other elevated places in the more northern portions of the Peninsula.

Cistothorus palustris paludicola Baird.

Tulé Wren.

(?) *Telmatodytes palustris paludicola* Belding, Proc. U. S. Nat. Mus., V. 1883, 546 (San José del Cabo).

(?) *Cistothorus palustris paludicola* Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 316 (San José del Cabo).

Mr. Belding gives this Marsh Wren as "rare" in his list of species found at San José del Cabo from April 1 to May 17, 1882. The birds which he saw on this occasion were probably only belated stragglers from the hordes which must regularly winter at this place, for in the autumn of 1887 Mr. Frazar found Tulé Wrens in immense numbers both here and at Santiago. They evidently came from the north, the vanguard of the flight arriving on September 21 (a single bird was seen on the 14th), but the bulk not until October 19, after which their numbers increased slowly but steadily up to November 4, when they simply swarmed in the patches of tall rushes and tules along the river. They were particularly abundant at Santiago, on November 22. A very few were seen at San José del Rancho in December, but none about La Paz in January, February, or March. To the northward Mr. Bryant has apparently met with only two specimens, both on Santa Margarita Island.

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[1] Zoe, IV. 1893, 245.

C. p. paludicola is very common, coastwise, in California wherever it can find suitable haunts. It is resident in the southern and central parts of the State and it winters sparingly as far north as Washington and Oregon, while its breeding range extends into British Columbia. It is said to migrate as far south as Guatemala.

Cistothorus palustris plesius Oberh.

Western Marsh Wren.

(?) *Telmatodytes palustris paludicola* (not *Cistothorus palustris paludicola* Baird) Belding, Proc. U. S. Nat. Mus., V. 1883, 546 (San José del Cabo).

(?) *Cistothorus palustris paludicola* (not of Baird) Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 316 (San José del Cabo).

Cistothorus palustris plesius Oberholser, Auk, XIV. 1897, 186–193 (orig. descr.; types from New Mexico and Utah; typical examples from Miraflores).

Mr. Oberholser says[1] that "very typical specimens of *plesius* have been taken at Miraflores, Lower California," but at what season he does not state. The large series of Marsh Wrens collected by Mr. Frazar at San José del Cabo includes representatives of this race and *paludicola* in about equal numbers. Which of the two birds — if either — is resident in the Cape Region I have no means of judging. Nor have I seen enough breeding specimens of either to form any definite opinion as to the value and constancy of the characters by which they have been separated. I may say in this connection, however, that I have a number of skins apparently typical of *plesius* which were obtained by Mr. L. M. Turner late in April, at Seattle, Washington, and hence practically on the Pacific coast, where, if I understand the case correctly, *paludicola* should be the breeding form, for *plesius*, according to Mr. Oberholser, breeds only in the interior.

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[1] Auk, XIV. 1897, 192.

Sitta carolinensis lagunae Brewst.

St. Lucas Nuthatch.

[*Sitta carolinensis*] var. *aculeata* Coues, Key N. Amer. Birds, 1872, 83, part.

Sitta carolinensis, var. *aculeata* Coues, Check List, 1873, 11, no. 38 a, part.

Sitta carolinensis aculeata (not of Allen) Ridgway, Nom., N. Amer. Birds (Bull. U. S. Nat. Mus., no. 21), 1881, 14, no. 51 a, part. Coues, Check List, 2d ed., 1882, 29, no. 58, part. Belding, Proc. U. S. Nat. Mus., VI. 1883, 347 (Victoria Mts.). A. O. U., Check List, 1886, 331, no. 727 a, part. Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 316 (Victoria Mts.).

Sitta carolinensis lagunae Brewster, Auk, VIII. 1891, 149 (orig. descr.; types from Sierra de la Laguna). Bryant, Zoe, II. 1891, 198 (Victoria Mts.)

S.[*itta*] *carolinensis aculeata* Ridgway, Man. N. Amer. Birds, 2d ed., 1896, 559, part.

[*Sitta carolinensis*] var. *lagunae* Dubois, Synop. Avium, fasc. IX. 1901, 681 (Basse-Californie).

Although this race has not been recognized by the A. O. U. Committee, I continue to regard it as a perfectly good subspecies. As I stated in connection with my original description it differs very constantly from *aculeata* of northern Mexico and the western United States in having decidedly shorter wings, slightly shorter tail, and much narrower, blackish, terminal markings on the outer tail feathers. These differences are not, perhaps, very conspicuous, but they seem to me to constitute better as well as obviously more readily available diagnostic characters than the slight dissimilarities in respect to color tones which alone serve to distinguish certain birds that have been accepted by the Committee as subspecifically distinct.

The St. Lucas Nuthatch is probably confined to the higher mountains south of La Paz, where it was first detected by Mr. Belding in 1883. To Mr. Frazar, however, is due the credit of collecting a sufficient series of specimens to bring out the slight but nevertheless very tangible differences which distinguish it from *aculeata*, to which Mr. Belding very naturally referred it. Mr. Frazar met with it only on the Sierra de la Laguna, where, at all seasons, it is a rather common bird inhabiting the pine forests at high elevations. Specimens shot early in May were incubating. It is possible that the White-bellied Nuthatches which Mr. Anthony found "rather rare but well distributed in the pines" on San Pedro Martir[1] may also belong to this form, but they are more likely to prove true *aculeata*.

[1] Zoe, IV. 1893, 246.

Parus inornatus cineraceus Ridgw.

Ashy Titmouse.

Lophophanes inornatus Coues, Check List, 1873, 9, no. 28, part; 2d ed., 1882, 28, no. 41, part. Ridgway, Nom. N. Amer. Birds (Bull. U. S. Nat. Mus., no. 21), 1881, 13, no. 38, part.

Lophophanes inornatus cineraceus Ridgway, Proc. U. S. Nat. Mus., VI. 1883, 154, 155 (orig. descr.; type from Laguna), 158, footnote (crit.; S. Lower Calif.), 347 (measurements). Belding, *Ibid.* (Victoria Mts.). Coues, Key N. Amer. Birds, 4th ed., 1894, 866 (descr.; Lower Calif.).

Parus inornatus cineraceus Ridgway, *Loc. cit.*, VIII. 1885, 354. A. O. U., Check List, 1886, 333, no. 733 b. Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 317 (Victoria Mts.); Zoe, II. 1891, 198 (Victoria Mts.).

P.[*arus*] *inornatus cineraceus* Ridgway, Man. N. Amer. Birds, 2d ed., 1896, 561 (descr.; s. portion of Lower Calif.).

[*Lophophanes inornatus*] var. *cineracea* Dubois, Synop. Avium, fasc. VII. 1901, 465 (Basse-Californie).

Mr. Ridgway states that this form differs from its nearest ally, *P. i. griseus*, in having generally grayer colors, paler coloring beneath, and a smaller bill. The bill of the type is described as *black*, and, as a second specimen afterwards taken by Mr. Belding agreed "exactly with the type," it is fair to assume that its bill was also black.

In my series of thirty-four examples, the clear grayish white of the under parts is perfectly constant and serves at once to distinguish the Lower California bird from *griseus*, which seems to be always dingy or smoky gray beneath. The color of the upper parts varies considerably with season, and is decidedly ashier in autumn than in spring; with several of my specimens it matches perfectly that of *griseus*, but with the majority it is slightly grayer. As far as the bills of the two birds are concerned, I am unable to make out any differences whatever, either of color or size. Without a single exception, the bills of my representatives of *cineraceus* are dark horn colored, precisely as in *griseus*, and they do not average smaller.

Several of my examples of *cineraceus* are marked in a curious manner with pale tawny brown, almost fawn color. This is nearly uniform in shade in the different birds, but is irregularly disposed, although always confined to the upper parts. In one specimen it forms a broad terminal band on the tail; in three others, a slight tipping on the crest, while in a fourth almost the entire crest is bright fawn color, in marked contrast with the ashy-gray crown and nape. The bird last mentioned has the greater wing coverts tinged with tawny, which forms a rather conspicuous light bar on each wing. It also shows an ill-defined light band across the back. All the specimens thus marked are adults, taken in May and June, and, in all, the plumage is worn and faded. It is possible that the peculiar coloring just described is caused by excessive fading, but I am inclined to regard it as analogous to the similar light markings found in *Melanerpes angustifrons* and certain other Woodpeckers.

The Ashy Titmouse appears to be strictly confined to the Cape Region, the bird found at San Pedro Martir, in the northern part of the Peninsula, being the closely related *P. i. griseus*, according to Mr. Bryant, whose failure to detect any representative of the *inornatus* group in the intermediate region makes it nearly certain that the habitat of *cineraceus* is quite cut off from that of its ally just mentioned. Indeed, its range appears to correspond closely, if not exactly, with that of the St. Lucas Nuthatch. Like the latter, it is a bird of the pine forests which cover portions of the summit and upper slopes of the high mountains near the southern extremity of the Peninsula. Here, according to Mr. Belding, it is "common from 3,000 feet altitude upward." On the Sierra de la Laguna Mr. Frazar found it quite as numerous in December as in May and June. None of the specimens killed at the latter season showed any indications of being about to breed, and the eggs, like those of many other birds which inhabit these mountains, are probably not laid much before midsummer.

Psaltriparus grindae Ridgw.

Grinda's Bush-Tit.

[*Psaltriparus*] *minimus* Coues, Key N. Amer. Birds, 1872, 81, 82, part (Pacif. coast).

Psaltriparus minimus Coues, Check List, 1873, 11, no. 35, part; 2d ed., 1882, 29, no. 53, part. Ridgway, Nom. N. Amer. Birds (Bull. U. S. Nat. Mus., no. 21), 1881, 14, no. 47, part.

Psaltriparus grindae Ridgway, Proc. U. S. Nat. Mus., VI. 1883, 155 (orig. descr.; type from Laguna), 158, footnote (crit.; S. Lower Calif.), 347 (measurements); Proc. Biol. Soc. Wash., II. 1884, 96 (a correction). Belding, Proc. U. S. Nat. Mus., VI. 1883, 347 (Victoria Mts.).

Psaltriparus minimus grindae Ridgway, Proc. U. S. Nat. Mus., VIII. 1885, 354. A. O. U., Check List, 1886, 337, no. 743 b. Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 317 (San Francisco and Victoria Mts.); Zoe, II. 1891, 198 (Victoria Mts.). Coues, Key N. Amer. Birds, 4th ed., 1894, 867 (descr.; Lower Calif.).

P.[*saltriparus*] *minimus grindae* Ridgway, Man. N. Amer. Birds, 2d ed., 1896, 565 (descr; s. portion of Lower Calif.).

[*Psaltriparus*] *grindae* Dubois, Synop. Avium, fasc. VII. 1901, 466 (Basse-Californie).

The characters claimed for this form by Mr. Ridgway are so constantly presented in the large series obtained by Mr. Frazar that I believe the bird to be a good species. The type, taken on February 2, was evidently in nuptial plumage. I can now add descriptions of the juvenal and first winter plumages.

Juvenal plumage: — (Male, No. 14,822, San José del Rancho, July 21, 1887). Differing from the adult in being ashier beneath, with a decided purplish tinge on the sides; the back paler bluish, the crown light purplish brown; the outer tail feathers with their outer webs ashy white to the shaft; the secondaries and wing coverts edged and tipped with grayish or rusty white.

First winter plumage: — (Male, No. 14,789, Sierra de la Laguna, November 28, 1887). Similar to the young just described, but with the crown deep purplish brown; the back darker or more slaty than in the adult; the wings and tail more bluish; the inner secondaries tipped with ashy white; the outer tail feathers with exceedingly narrow light margins on their outer webs.

A moulting specimen (No. 14,828), taken on July 28, 1887, has the forehead covered with fresh feathers of the same deep purplish brown as No. 14,789, while the worn and faded feathers on the occiput are those of the nuptial dress, showing that the adult assumes a distinctive autumn plumage. Among the spring adults in my series, however, there is much individual variation in respect to the color of the crown which varies from very pale isabella to purplish brown nearly as deep and rich as that of autumnal birds.

Like the Ashy Titmouse, Grinda's Bush-Tit is confined to the mountains south of La Paz. It is represented in the northern portions of the Peninsula "from El Rosario northward" (Bryant) by the closely-allied form, *P. minimus californicus*, the two being separated geographically by a region over four hundred miles in width, where no member of the genus is known to occur. Mr. Belding (who discovered both birds in 1883) draws no distinction between the respective vertical ranges of *P. i. cineraceus* and *P. grindæ*, but Mr. Frazar found that the latter has much the more extended *vertical* distribution of the two, occurring almost as numerously about San José del Rancho as on the Sierra de la Laguna. It is a sedentary species, of which each individual bird probably spends its entire life within a very limited area, for Mr. Frazar noticed no marked seasonal variations in the number of its representatives at any of the localities which he visited.

A nest found on May 24 in the top of a small pine about eight feet above the ground, on the Sierra de la Laguna, is similar in shape to the nests of *P. m. californicus* and *P. plumbeus*. It is nine inches long, with a diameter varying from two to two and one half inches. The entrance hole is in one side near the top. The walls are composed of small, dry leaves, fern-down, catkins, spiders' cocoons, yellowish usnea and grayish lichens, all these materials being felted into a thick, tenacious fabric of a generally mixed brown and grayish color. There were no eggs, the nest being not quite finished when taken.

Auriparus flaviceps lamprocephalus OBERH.[1]

BAIRD'S VERDIN.

Paroides flaviceps (not *Aegithalus flaviceps* SUNDEVALL) BAIRD, Proc. Acad. Nat. Sci. Phila., 1859, 301 (Cape St. Lucas), 304 (crit.; Cape St. Lucas).

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[1] Most of the differences which distinguish this subspecies from true *flaviceps* were originally pointed out by Professor Baird (Rev. Amer. Birds, pt. I. 1864, 85, 86).

Auriparus flaviceps (not *Aegithalus flaviceps* Sundevall) Baird, Rev. Amer. Birds, pt. I. 1864, 85, 86, part (crit.; Cape St. Lucas). Cooper, Orn. Cal., 1870, 51, part (Cape St. Lucas). Coues, Check List, 1873, 11, no. 37, part; 2d ed., 1882, 29, no. 56, part. Baird, Brewer, and Ridgway, Hist. N. Amer. Birds, I. 1874, 112, 113, part (breeding at Cape St. Lucas; nesting habits). Salvin and Godman, Biol. Centr.-Amer., Aves, I. 1880, 59, part (breeding at Cape St. Lucas; descr. male from Cape St. Lucas). Ridgway, Nom. N. Amer. Birds (Bull. U. S. Nat. Mus., no. 21), 1881, 14, no. 50, part. Belding, Proc. U. S. Nat. Mus., V. 1883, 535 (Cape Region), 547 (breeding at La Paz); VI. 1883, 345 (Cape Region). A. O. U., Check List, 1886, 338, no. 746, part. Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 318 (throughout Peninsula). Townsend, Proc. U. S. Nat. Mus., XIII. 1890, 137 (Cape St. Lucas).

[*Auriparus*] *flaviceps* Coues, Key N. Amer. Birds, 1872, 82, part (Lower Calif.).

A.[*uriparus*] *flaviceps* Coues, Key N. Amer. Birds, 4th ed., 1894, 269, part (Lower Calif.). Ridgway, Man. N. Amer. Birds, 2d ed., 1896, 565 part (Lower Calif.).

Auriparus flaviceps lamprocephalus Oberholser, Auk, XIV. 1897, 390–394 (orig. descr.; type from Cape St. Lucas). A. O. U. Comm., Auk, XVI. 1899, 126, no. 746 a.

[*Auriparus flaviceps*] var. *lamprocephala* Dubois, Synop. Avium, fasc. VII. 1901, 468 (Basse-Californie).

Mr. Bryant says that this Verdin is "a common species throughout the peninsula," but he adds that Mr. Belding doubts if it occurs "north of lat. 32°, unless on the eastern side." Mr. Anthony reports it as "quite common in all of the country south of San Quintin," but he does not mention meeting with it anywhere to the northward of that place.[1] These statements were made, of course, before the subspecies *lamprocephalus* had been separated by Mr. Oberholser, who gives its habitat as "California inferior australis," adding "no specimens from the upper half of Lower California have been examined." Mr. Bryant, however, in a previous paper,[2] in which he proposed to distinguish the same bird under a name which has been since shown by Mr. Oberholser to be untenable, refers to it apparently all the specimens of the Verdin which he had "collected in Lower California," as well as others from Los Angeles and San Diego counties, California.

Mr. Frazar found Baird's Verdin abundant everywhere in the Cape Region except on the Sierra de la Laguna, where none were met with. It was breeding at La Paz in March, at Triunfo in April, and apparently at San José del Cabo in *November*, for on the third of that month Mr. Frazar found two nests about half completed on which the birds were busily at work. A week later another Verdin was noticed carrying feathers in its bill, doubtless for the lining of its nest, and still later (on November 17) a fourth was observed at Santiago collecting building material.

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[1] Auk, XII. 1895, 143.

[2] Zoe, I. 1890, 149.

Regulus calendula (Linn.).

Ruby-crowned Kinglet.

Regulus calendula Belding, Proc. U. S. Nat. Mus., VI. 1883, 347 (Victoria Mts.). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 318 (Victoria Mts.); Zoe, II. 1891, 198 (Victoria Mts.).

Although this species has thus far defied the "hair-splitters" with some success, it does not seem to be entirely free from geographical variation. At least in the series before me it is possible to make out three forms, of which that from the eastern United States is the smallest and most richly colored, that from the Middle Province the largest and grayest, that from the Northwest coast intermediate in size between the other two, and, like many birds from this region, very deeply colored.[1] The differences between extreme, or what may be called typical, examples of these forms are obvious and easily made out, but they do not seem to be sufficiently constant in the birds from any one region to be worth special recognition. It should be mentioned, however, that most of my specimens were taken either during migration or in their winter quarters, and the examination of good series of breeding birds would perhaps lead me to a different conclusion from that just expressed.

The five specimens collected in the Cape Region by Mr. Frazar were all shot on the Sierra de la Laguna. They belong to the large gray form above mentioned.

Mr. Belding names the Ruby-crowned Kinglet in his list of mountain birds as "moderately common; from 3,000 feet altitude upward." Mr. Frazar found it only on the Sierra de la Laguna, where he shot a single specimen, a female, on April 27, and saw a number during the last week of November and the first two days of December. Mr. Bryant does not mention meeting it, but states that "on San Pedro Martir Mr. Anthony saw it up to 11,000 feet altitude, and down to the coast in winter and spring," as well as "in the pines the last of April, at 8,500 feet elevation." It is not probable that it breeds in Lower California even at high altitudes.

The Ruby-crowned Kinglet is merely a winter visitor to the coast districts of California, but it breeds in the Sierras from latitude 38° northward to Alaska. It is common in western Mexico in winter, and goes as far south as Guatemala.

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[1] This is probably the form which Dr. Palmer has recently described (Auk, XIV. 1897, 399), from Sitka, Alaska, under the name *R. c. grinnelli*. According to Dr. Palmer, however, the Sitka bird is smaller, instead of larger, than true *calendula*.

Polioptila caerulea obscura Ridgw.

Western Gnatcatcher.

Polioptila caerulea (not *Motacilla caerulea* Linnaeus) Baird, Rev. Amer. Birds, pt. I. 1864, 74, 75, part (crit.; Cape St. Lucas). Belding, Proc. U. S. Nat. Mus., V. 1883, 534 (Cape Region); VI. 1883, 346, 347 (crit.; Victoria Mts.). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 318 (Cape Region; Victoria Mts.).

P.[olioptila] caerulea obscura Ridgway, Proc. U. S. Nat. Mus., V. 1883, 534, 535 (provis. name based on specimens from San José, Lower California, California, Arizona, etc.; measurements of bird from San José, etc.).

Although the characters which distinguish the Western Gnatcatcher from *P. caerulea* are rather slight, they are well maintained in the series of over thirty specimens before me. The most constant difference is that relating to the extent of the white on the outer tail feathers, *P. c. obscura* having the white much more restricted than *P. caerulea.*

The Western Gnatcatcher is a rather common resident of the Cape Region, where it appears to be indifferent to conditions of mean temperature or environment, for it occurs nearly everywhere from the seacoast (La Paz and San José del Cabo) to the summits of the highest mountains (Sierra de la Laguna). Mr. Frazar found it breeding at San José del Rancho in July. His first nest, discovered on the 7th, contained four eggs on the point of hatching, and was not disturbed. Two others, taken respectively on the 14th and 19th of the month, had full sets of four eggs each, all freshly laid. One of these nests, built in the fork of a bush at a height of about five feet, measures as follows: Greatest external diameter, 2.25; greatest external depth, 2.00; internal diameter at top, 1.30; internal depth, 1.10; greatest thickness of walls, .50. The exterior is composed of gray, hemp-like, vegetable fiber and narrow strips of reddish brown bark, and is decorated with a very few lichens, all these materials being over-wrapped and kept in place by a nearly invisible tissue of spider-web. The interior is lined with fragments of silky cocoons and a few feathers. The other nest, which was placed in the fork of a small tree about ten feet above the ground, and which is essentially similar to the specimen just described, save that it has no lichens whatever, measures externally 2.15 in diameter by 2.10 in depth; internally, 1.40 in diameter by 1.50 in depth. Both nests are smaller and more compact than any of the nests of *P. caerulea* in my collection. The eggs of one set are ovate in shape, and measure respectively: .59 × .44, .59 × .45, .60 × .45 and .60 by .44. The ground-color is greenish white; the markings, which are generally distributed, but most numerous and crowded about the larger ends, are reddish brown, purplish, and lavender. The eggs of the other set are blunt ovate, and measure respectively: .56 × .43, .56 × .44, .56 × .43 and .57 by .45. The ground-color is like that of the eggs just described, but almost all the spots are bright reddish brown and restricted to the larger ends, where they are grouped in what is known as the "wreath pattern."

In Lower California *P. c. obscura* seems to be practically confined to the Cape Region, for to the northward Mr. Bryant has obtained only a single specimen — "at San Julio, near Comondu, in March, 1888." It is also found in southern and central California, as well as in southern Arizona and northwestern Mexico.

Polioptila plumbea (Baird).

Plumbeous Gnatcatcher.

Polioptila melanura Baird, Proc. Acad. Nat. Sci. Phila., 1859, 301 (Cape St. Lucas), 304 (crit.; Cape St. Lucas); Rev. Amer. Birds, pt. I. 1864, 67, 68 (descr.; crit.; Cape St. Lucas). Baird, Brewer, and Ridgway, Hist. N. Amer. Birds, I. 1874, 81, 82 (descr. nest from Cape St. Lucas, birds abundant).

Polioptila plumbea Belding, Proc. U. S. Nat. Mus., V. 1883, 535 (Cape Region), 547 (San José del Cabo). Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 318 (Cape St. Lucas; Cape Region). Townsend, Proc. U. S. Nat. Mus., XIII. 1890, 137 (Cape St. Lucas; La Paz).

Of this Gnatcatcher, Mr. Frazar's collection contains only three males in full plumage, all from La Paz, two taken in March, one in April. Two have the lores mixed slightly with ashy. In the third the lores are wholly ashy white, and there is a whitish spot a little above and behind the eye. All my Lower California specimens seem to have shorter tails than the birds which inhabit Arizona and Texas.

Mr. Belding characterizes the Plumbeous Gnatcatcher as "very common," and mentions seeing a brood of young just out of the nest on April 14, 1882. Mr. Frazar met with it only at La Paz and San José del Cabo and not in any numbers at either place. In fact, he is inclined to regard it as rather rare in the Cape Region. Mr. Bryant "found it on Santa Margarita Island, and from the west coast to the Gulf in about lat. 26° N." A little further to the northward on the Peninsula, as well as in southern California, it is replaced by the closely allied *P. californica*, but *P. plumbea* reappears in southern Arizona, and is common throughout northwestern Mexico.

Hylocichla ustulata (Nutt.).

Russet-backed Thrush.

Mr. Frazar collected four males of this species on the Sierra de la Laguna in May, two on the 4th, one on the 7th, and one on the 16th. He also obtained a female at Triunfo on June 13th. All of these birds are typical *ustulata* (as now restricted), and one of them (the specimen taken on May 7) is ultra-typical of that form, having the under tail coverts and crissum heavily washed with rusty ochraceous, the buffy of the jugulum exceptionally rich, and the rufous tinge on the flanks, wings, tail, and upper parts generally, deeper and more pronounced than in any of the specimens in my collection from British Columbia or Washington. If Mr. Frazar's birds were, as both he and I believe, breeding or about to breed in the region where they were obtained, they furnish an interesting case of interrupted distribution, for true *ustulata* is not known to occur in summer in the southern or central portions of California, where it is replaced by the slightly paler, grayer form *H. u. oedica.*

The Russet-backed Thrushes found by Mr. Frazar on the Sierra de la Laguna in May were all met with in rather open oak and pine woods near water, where they were apparently settled and preparing to breed. None were seen elsewhere save at Triunfo, where a single female was shot on June 13 in a shaded arroyo. This bird was unmistakably incubating, and must have had a nest and eggs somewhere in the neighborhood. These are the only known instances of the occurrence of the Russet-backed Thrush in the southern part of Lower California, but near the northern boundary it was "seen at Hansen's as late as May 14, 1884, by Mr. Belding, and after the middle of May southeast of San Rafael."[1] Mr. Anthony found it as late as May 25 on San Pedro Martir, where, he thinks, "it is possibly a resident of the pines, but those taken showed little enlargement of the ovaries, and it is more probable that they were belated migrants."[2]

Hylocichla guttata (Pall.).

Alaska Hermit Thrush.

(?) *Hylocichla unalascae* Ridgway, Proc. U. S. Nat. Mus., V. 1883, 533, footnote, part (Cape St. Lucas).

Hylocichla unalascae Belding, *Ibid.*, VI. 1883, 346, part (Casa Pintada, Victoria Mts., Feb. 17, 1883).

Turdus aonalaschkae Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 319, part (Victoria Mts.).

Soon after concluding a study of the smaller western forms of the Hermit Thrush, some of the results of which are given in this paper under *Hylocichla guttata nana*, I asked Mr. Oberholser, who had seen my specimens and was aware of the changes which I had decided to make in the names of two of the forms, to carefully examine all the skins in the National Museum from the Cape Region, and let me know his opinion regarding them. In reply to this request, he wrote me, under date of April 30, 1902, as follows: "I have been unable to find any of Xantus's specimens, . . . but discovered three collected by Belding, as follows: —

"One from Casa Pintada, Lower California, February 17, 1883, is unquestionably *guttata*.

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[1] Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 319.

[2] Zoe, IV. 1893, 246.

"One from Laguna, Lower California, February 1, 1883, is intermediate between *guttata* and *nana*, but apparently nearer the former.

"One from Casa Pintada, February 17, 1883, is quite typical *nana*."

Hylocichla guttata auduboni (BAIRD).

AUDUBON'S HERMIT THRUSH.

(?) *Hylocichla unalascae* RIDGWAY, Proc. U. S. Nat. Mus., V. 1883, 533, footnote, part (Cape St. Lucas). BELDING, *Ibid.*, VI. 1883, 346, part (Victoria Mts.).

(?) *Turdus aonalaschkae* BRYANT, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 319, part (Victoria Mts.).

Audubon's Thrush is represented in Mr. Frazar's collection by six skins, all obtained on the Sierra de la Laguna between May 11 and June 8. One of these birds (No. 14,515, ♀ May 27, 1887) is small enough to be referred to the so-called "*sequoiensis*" of California, a form which does not seem to me worth recognition. The others agree closely in size, as well as in every other respect, with breeding specimens of *auduboni* from the Rocky Mountain region.

This Thrush, which has not been previously reported from any portion of Lower California, was found by Mr. Frazar only on the Sierra de la Laguna, where it inhabited deep, moist, shady cañons, and also, to some extent, dry pine woods. It was not numerous, but was seen almost daily during May, and up to the 9th of June when Mr. Frazar started for Triunfo. The males were in full song, and there can be little doubt that they and their mates were settled for the season and preparing to breed on this mountain. It is singular that no form of Hermit Thrush was found on San Pedro Martir by Mr. Anthony.

H. a. auduboni breeds rather commonly in the mountains of California and as far south as Orizaba in Mexico, while it has been taken in Guatemala in winter.

Hylocichla guttata nana (AUD.).

DWARF HERMIT THRUSH.

(?) *Hylocichla unalascae* RIDGWAY, Proc. U. S. Nat. Mus., V. 1883, 533, footnote, part (Cape St. Lucas).

Hylocichla unalascae BELDING, *Ibid.*, VI. 1883, 346, part (Casa Pintada, Victoria Mts., Feb. 17, 1883).

Turdus aonalaschkae, BRYANT, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 319, part (Victoria Mts.).

As Mr. Nelson has pointed out,[1] the application of Gmelin's barbarous name *aonalascensis* (or *aonalaschkae*, as it is now generally written) to the Dwarf Hermit Thrush is ill advised. Latham's description upon which the name is based is altogether too indefinite to be determinable. If his bird was really a Hylocichla at all — which is doubtful — it is most likely to have been the Gray-cheeked Thrush. The name *guttata* of Pallas, on the other hand, rests on a careful description, which, although taken from a young bird, unmistakably relates to the Alaska Hermit Thrush.

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[1] Rept. Nat. Hist. Coll. Alaska, 1887, 218, 219.

Mr. W. H. Osgood has lately separated [1] this bird into two forms, a gray one, for which he retains the name *aonalaschkae*, and of which he has examined summer specimens from Nushagak, Kukak Bay, and Kadiak Island, Alaska, and a browner, more richly colored bird which breeds on the "islands and coasts of British Columbia and southeastern Alaska" and which he proposes to call *verecunda*. Still a third form — *slevini* — said to be the grayest of them all and to inhabit in summer the "cloudy coast belt of California, from southern Monterey County northward, locally at least, to Sonoma County" has been since named and described by Mr. Grinnell.[2] I have a large series of Dwarf Thrushes from California, Oregon, and British Columbia, but few, if any, of them can be safely assumed to have been taken on their breeding grounds. Nevertheless, they apparently represent all three of the forms just mentioned.

With *slevini* it is unnecessary to deal in this connection, for it is not known to have occurred in the Cape Region. *Aonalaschkae* — or *guttata*, as I prefer to call it — and *verecunda* seem to me sufficiently unlike to be recognized as distinct subspecies, provided they really occupy different breeding grounds; but *verecunda*, as Mr. Osgood evidently suspected might prove to be the case, is nothing more nor less than the *nanus* of Audubon. I am aware, of course, that several ornithologists have argued [3] — and with some plausibility because of the lack of definite evidence to the contrary — that this name was based primarily on an exceptionally small specimen of the Hermit Thrush of eastern North America and not on the skin which Audubon mentions having received from the Columbia River. Probably no one of these writers was aware that this skin is still in existence — in the collection of the Museum of Comparative Zoölogy. It bears three labels. On the original one is inscribed *in Audubon's own handwriting*, "*Turdus terrestris*. Aud. Columbia River," to which is added, in Mr. John Cassin's hand and in red ink, "J. J. Audubon's label." The second label is evidently Mr. Cassin's, and reads, "John Cassin — Philadelphia — 1864. *Turdus nanus*, Audubon, Dr. J. K. Townsend's collection Mr. John G. Bell,[4] Columbia River." The third label is that of the Museum of Comparative Zoölogy, which acquired the specimen many years ago by exchange with Brown University.

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[1] Auk, XVIII. 1901, 183–185.

[2] *Ibid.*, 258–260.

[3] Cf. Brewer, Proc. Bost. Soc. Nat. Hist. XVII. 1875, 438, footnote; Coues, Birds Col. Valley, 1878, 22–25; Osgood, *Loc. cit.*

[4] Mr. Bell could not well have had anything to do with the capture of this specimen, but Mr. Cassin may have obtained it from him. When I first made his acquaintance, some thirty years ago, he still had several of Audubon's skins in his possession.

This interesting bird, to which my attention was first called by Mr. Walter Faxon, is an exceptionally brown, richly-colored specimen of the form which Mr. Osgood has called *verecunda*.[1] Although in full winter plumage, it retains on its wing coverts several of those rusty, tear-shaped spots which are invariably characteristic of the juvenal plumage of most Hylocichlae, and which also frequently reappear in their first winter plumages. On comparing this specimen with the life-size figure of *Turdus minor* in the elephant folio edition of Audubon's immortal work,[2] Mr. Faxon and I find that the two correspond satisfactorily in respect to their general coloring (that of the figure is somewhat browner, however, than that of the skin) and so very minutely in the measurements of the various parts as to leave no doubt in our minds that the bird here considered was that from which Audubon's figure of *T. minor* was drawn. It was probably taken by Dr. Townsend soon after his arrival at the Columbia River, in the autumn of 1834, and should not be confounded with the "female specimen of a Thrush" procured "on the Columbia River on the 19th June 1838," by Dr. Townsend, and said by Audubon "to differ in no other respect from specimens of *Turdus Wilsonii* than in having some of the spots on the sides of the neck and the breast of a darker brown."[3] The latter measured "seven inches two and a half twelfths in length," and was probably an Oregon Thrush (*Hylocichla ustulata*).

Turdus nanus was afterwards based by Audubon[4] partly on his plate of *T. minor*, but also on a detailed description which closely fits the Columbia River specimen now in the Museum of Comparative Zoölogy, even the tear-shaped spots being mentioned in the following terms: "Secondary coverts tipped with yellowish-red, which on some of the inner runs a little way along the shaft." Some of the measurements given in connection with this description do not, however, agree with those of the Townsend skin. Very possibly they were taken by Audubon from his note-book and originally from a fresh specimen of a small eastern bird.

These facts have convinced both Mr. Faxon and me that the specimen just considered may be safely regarded as the actual type of *Turdus nanus*. If we are correct in so thinking, this name, as I have already indicated, must necessarily take the place of *verecunda*, provided the separation proposed by Mr. Osgood be adopted.

All of the four small Hermit Thrushes collected in the Cape Region by Mr. Frazar are apparently referable to *nana*, although one of them (No. 14,527, ♀, Triunfo, December 5, 1887) is somewhat too gray to be typical of that form, and perhaps is intermediate between it and true *guttata*. Another, killed on the Sierra de la Laguna on April 27, is in such worn and faded plumage as to suggest that it may have been breeding.

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[1] I have directly compared it with Mr. Osgood's series of breeding specimens (including the type) of this form from the Queen Charlotte Islands.

[2] Birds Amer., pl. 419, fig. 1.

[3] Orn. Biog. V. 1849, 203, 204.

[4] *Loc. cit.*, 204–206.

The Dwarf Thrush was found in January at Cape St. Lucas by Mr. Xantus, and Mr. Belding has reported it "common; possibly resident" in the "Victoria Mountains." It is probable, however, that some of the birds seen by the latter observer were *H. g. auduboni*, which is not uncommon, and doubtless breeds in these mountains, and that the Dwarf Thrush occurs in the Cape Region only during the migrations and in winter, and then in no great numbers. This, at least, is Mr. Frazar's opinion, and it is confirmed, in the main, by the evidence afforded by his skins, although it must be admitted that it is difficult to account for the excessively worn and generally shabby condition of plumage of the specimen above referred to, other than by the assumption that it was a breeding bird. If *auduboni* and *guttata* really pass the summer together or in close proximity in the Cape Region without *interbreeding*, the case will be one of peculiar interest in view of the fact that both are regarded as mere geographical forms of the same species.

Mr. Bryant states that he "saw a few" "Dwarf Thrushes" on Santa Margarita Island in January, 1888. They do not appear to have been met with anywhere in the central or northern portions of the Peninsula, either by him or by Mr. Anthony.

Merula migratoria propinqua (Ridgw).

Western Robin.

The relationship of a Robin taken by Mr. Frazar at San José del Rancho on December 22, 1887, is open to some doubt, for the specimen is apparently intermediate between *migratoria* and *propinqua*, combining the large, distinct, white tail spots of the former with the decidedly ashy back, and restricted black on the head, of the latter. On the whole, however, the bird seems to be nearest *propinqua*, a form which has not been previously reported from the southern portion of Lower California, although in the northern districts it is not uncommon in winter and early spring, feeding chiefly on manzanita berries and ranging at least as far southward as San Quintin.[1]

The Western Robin is a winter visitor only, to the lowlands of California, but it breeds in the mountains as far south as Los Angeles county and northward into British Columbia. In Alaska it is unknown, all the Robins of that region being, apparently, true *migratoria*. Salvin and Godman state[2] that the latter occurs in summer in the mountains of Orizaba, and that they have examined a young bird in spotted plumage taken near the City of Mexico, while they make no mention of *M. m. propinqua*, but all my winter specimens from western Mexico, as well as several breeding birds shot at Pinos Altos and Jesus Maria, are typical *propinqua*.

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[1] Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 319.

[2] Biol. Centr.-Amer., Aves, I. 1879, 20, 21.

Merula confinis (Baird).

St. Lucas Robin.

Turdus confinis, Baird, Rev. Amer. Birds, pt. I. 1864, 29–31 (orig. descr.; type from Todos Santos). Elliot, Illustr. New and Unfig. N. Amer. Birds, I. 1869, introd. ("*T. migratorius;*" Todos Santos). Cooper, Orn. Cal., 1870, 9, 10 (descr.; crit.; figures head; Cape St. Lucas). Baird, Brewer, and Ridgway, Hist. N. Amer. Birds, I. 1874, pl. 2, fig. 1. Coues, Birds Col. Valley, 1878, 9 (variety of *Turdus migratorius*). Seebohm, Cat. Birds Brit. Mus., V. 1881, 222 (descr.; Todos Santos).

[*Turdus*] *confinis* Gray, Hand-list, I. 1869, 258, no. 3,756. Dubois, Synop. Avium, fasc. VI. 1901, 401 (Basse-Californie).

[*Turdus migratorius*] var. *confinis* Coues, Key N. Amer. Birds, 1872, 72 (descr.; Cape St. Lucas).

Turdus migratorius, var. *confinis* Coues, Check List, 1873, 5, no. 1 a. Baird, Brewer, and Ridgway, Hist. N. Amer. Birds, I. 1874, 27, 28, pl. 2, fig. 1 (descr.; crit.; Todos Santos). Jasper, Birds N. Amer., 1878, 173, pl. 114, fig. 21 (Cape St. Lucas).

Merula confinis Ridgway, Nom. N. Amer. Birds (Bull. U. S. Nat. Mus., no. 21), 1881, 11, 60, 74, no. 8; Proc. U. S. Nat. Mus., V. 1883, 533, footnote (Todos Santos); VI. 1883, 158, 159 (crit.; Todos Santos; Laguna). Belding, *Ibid.*, 346 (crit.; Laguna trail; Victoria Mts.). A. O. U., Check List, 1886, 345, no. 762. Bryant, Proc. Calif. Acad. Sci., 2d ser., II. 1889, 319 (Todos Santos; Victoria Mts.); Zoe, II. 1891, 198 (Victoria Mts.). Emerson, *Ibid.*, I. 1890, 46 (Hayward's, Calif.). Keeler, *Ibid.*, 250 (Hayward's, Calif.). Allen, Auk, X. 1893, 142 (tropical type).

Turdus migratorius confinis Coues, Check List, 2d ed., 1882, 23, no. 3.

T.[*urdus*] *confinis* Coues, Key N. Amer. Birds, 4th ed., 1894, 244, 245 (descr.; Lower Calif.).

M.[*erula*] *confinis* Ridgway, Man. N. Amer. Birds, 2d ed., 1896, 578 (descr.; near Cape St. Lucas).

Of this hitherto rare bird, Mr. Frazar collected over one hundred and fifty specimens. These represent very fully the nuptial and late autumn plumages, but unfortunately do not include examples of the young in first plumage. The sexes are not certainly distinguishable, either by size or color, although the females average a trifle smaller than the males and are usually whiter beneath, with less spotting on the throat. In spring birds the color of the under parts varies from creamy buff to light cream, or creamy white. November and December examples have the under parts pure, deep, almost ochraceous, buff. Fully ten per cent of the entire series show more or less ashy on the breast, this varying in tone and extent from a few pale gray, nebulous spots near the tips of the feathers to numerous brownish-ashy blotches which form a broad and almost solid pectoral band. This clouding is most common and pronounced in autumnal specimens, but some of these lack it wholly, while it sometimes occurs in spring birds, a few of which, indeed, are quite as conspicuously marked as are any of the autumn specimens. Nevertheless, it is apparently a characteristic of immaturity which, perhaps, does not wholly disappear before the second or third year of the bird's life.

The amount of white on the sides of the head, upon which some stress has been laid by writers as a probable specific character, proves to be highly variable. Some birds have a distinct white ring completely encircling the eye, and, in addition, a broad white stripe extending along the side of the head above the eye nearly to the nostril. In others the white is confined to the eyelids, and a short space a little above the eye, the remainder of the sides of the head being perfectly plain and of about the same color as the crown. These extremes are connected by various intermediate styles. Similarly, the throat in some birds is chiefly white with only a few narrow, dark markings, while in others the streaks are so broad and numerous as to be almost fused. The majority of specimens have the tail perfectly plain, or with at most a very narrow light edging on the tips of the outer feathers. In two of my skins, however, the outer two feathers are conspicuously white-tipped, and in one of these birds the white spot extends back ten one-hundredths of an inch on the outermost feathers.

The bill is perhaps the most variable feature of all, being sometimes long, slender, strongly hooked, and distinctly notched at the tip, sometimes broad and deep, with the tip of the upper mandible barely extending beyond that of the lower. The color of the bill is highly variable. In most of the spring specimens it is wholly pale, pure yellow, with usually, but not invariably, a dusky space at the tip of the upper mandible. One bird (No. 14,469, April 30) has the base of the lower, and the middle of the upper, mandible wood brown, the remainder of the bill being dark horn-colored. This is about the average style of coloring with autumn specimens, but some of the latter have the entire upper, and the terminal halt of the lower mandible horn-colored, while in a few both mandibles are nearly uniform yellowish brown. Although a dark bill is not always correlated with the presence of ashy clouding beneath, I am inclined to believe that, like the latter, it indicates immaturity, and is usually, if not always, characteristic of young birds, certainly persisting during the first autumn, and, with some individuals, probably through the following spring and summer, also.

This interesting species, originally described by Professor Baird from a bird killed by Mr. Xantus at Todos Santos in the summer of 1860, was practically rediscovered by Mr. Belding in February, 1883, but one specimen besides the type having been taken up to this time. Mr. Belding gives the following account of his experience: "Only about a dozen Cape Robins were seen, and these were all on the Laguna trail. About half were found singly, one as low as 2,500 feet above the sea-level. Mr. Cipriano Fisher, an American, who has often hunted deer at Laguna, informed me that Robins were sometimes abundant there. This may be the case when the berries of the California Holly (*Heteromeles*), which grows abundantly in the neighborhood, are ripe."

Mr. Frazar was the next to meet the St. Lucas Robin in its native haunts. He found it first on the Sierra de la Laguna, during his ascent of this mountain on April 26, 1887. It was common at this date, and by the end of May, exceedingly abundant, for its numbers continued to increase during nearly the whole of Mr. Frazar's stay, but up to the time of his departure (June 9), it was invariably seen in flocks, and none of the many specimens examined showed any indications that their breeding season was at hand. The people living on the mountain asserted that the birds do not lay before July. Mr. Frazar found a number of old nests which were constructed precisely like those of the common Robin, and placed in similar situations. The males were frequently heard singing. "The song resembles that of the eastern Robin, but is weaker and less distinct, reminding one of the efforts of a young bird just learning to sing. I did not hear a single loud, clear note."

During his second visit to La Laguna, Mr. Frazar saw in all only ten St. Lucas Robins, — one on November 28, two on November 30, one on December 1, and six on December 2. This led him to conclude that most of them leave the mountains in winter, a supposition speedily confirmed, for about two weeks later (December 18–25) he found them abundant at San José del Rancho. At this place a few breed, also, for three were seen during July, and one of them, a female, shot on the 27th, was incubating, and must have had a nest and eggs somewhere in the immediate neighborhood. A fourth was met with on June 9, about ten miles from the base of the Sierra de la Laguna on the road to Triunfo.

The St. Lucas Robin is evidently one of the most characteristic species of the Cape Fauna, for it does not range even so far to the northward as La Paz, and, according to Mr. Bryant, is unknown to the people living in the central and northern portions of the Peninsula. A single straggler, which is said to be perfectly typical, was taken, however, at Hayward's, California, on January 2, 1882, by Mr. W. Otto Emerson.[1] This is the only known instance of the occurrence of the species outside the borders of its little realm near the southern extremity of Lower California.

The total number of species and subspecies of birds from the Cape Region of Lower California, included in the foregoing list, is as follows: —

Species	167
Subspecies	88
Total . . .	255

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[1] Zoe, I. 1890, 46. There is a subsequent record by Mr. C. A. Keeler (*Ibid.*, 250) which apparently relates to the same bird, although the date of its capture is given as January 27, 1883.

LIST OF SPECIES AND SUBSPECIES DESCRIBED AS NEW

Totanus melanoleucus frazari.
Megascops xantusi.
Bubo virginianus elachistus.
Tachycineta thalassina brachyptera.

LIST OF SPECIES AND SUBSPECIES RECORDED FOR THE FIRST TIME FROM THE CAPE REGION OF LOWER CALIFORNIA

Larus atricilla.
Sterna caspia.
  hirundo.
  antillarum.
Hydrochelidon nigra surinamensis.
Sula brewsteri.
Ardetta exilis.
Ardea virescens anthonyi.
Rallus virginianus.
Gallinula galeata.
Phalaropus lobatus.
Macrorhamphus scolopaceus.
Tringa maculata.
  bairdii.
Totanus flavipes.
Heteractitis incanus.
Charadrius dominicus.
Arenaria morinella.
Archibuteo ferrugineus.
Haliaeetus leucocephalus.
Falco peregrinus anatum.
  columbarius richardsonii.
  sparverius deserticolus.
Coccyzus americanus occidentalis.
Chaetura vauxii.
Molothrus ater.
Astragalinus psaltria arizonae.
Spiza americana.
Hirundo erythrogaster.
Vireo vicinior.
Mniotilta varia.
Dendroica aestiva sonorana.
    rubiginosa.
Hylocichla ustulata.
   guttata auduboni.
Merula migratoria propinqua.

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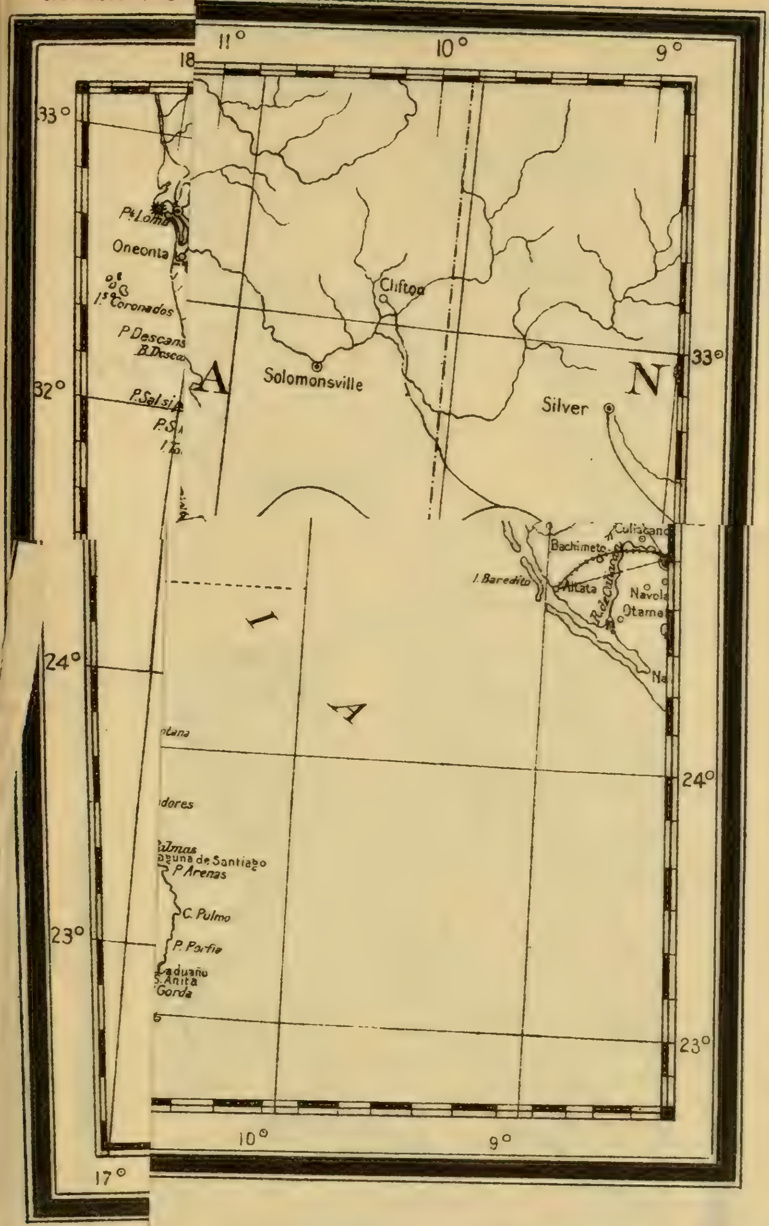
LOWER CALIFORNIA AND ADJACENT REGIONS.

Slightly modified from the map of Hendges, published by the Bureau of the American Republics, 1900.

The dotted lines define the Cape Region.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Altata
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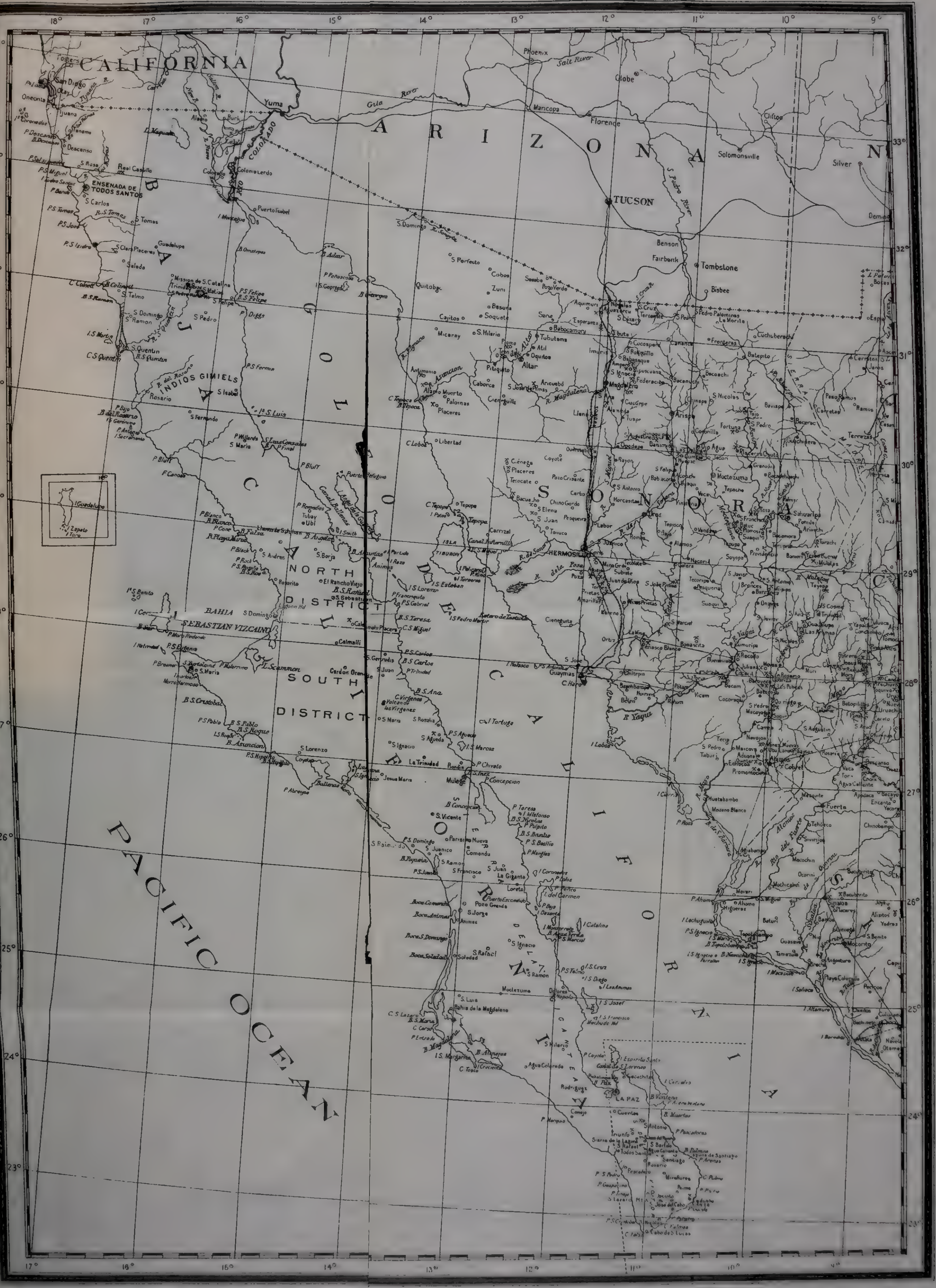
P Arenas
C. Pulmo
P. Porfia
Aduaño
S. Anita
Gorda

Brewster: Cape Region Birds.


CALIFORNIA
ARIZONA
SONORA
BAJA CALIFORNIA
GOLFO DE CALIFORNIA
PACIFIC OCEAN
NORTH DISTRICT
SOUTH DISTRICT
INDIOS GIMIELS
BAHIA S. SEBASTIAN VIZCAINO
TUCSON
HERMOSILLO
LA PAZ
ENSENADA DE TODOS SANTOS
Yuma
San Diego
Phoenix
Tombstone
Guaymas
Mulege
Loreto
Bahia de la Magdalena
I. Guadalupe
COLORADO
Gila River
Salt River
S. Pedro River
R. Yaqui
ISLA TIBURON
Cabo de S. Lucas
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THE CHIMAEROIDS (CHISMOPNEA RAF., 1815; HOLOCEPHALA MÜLL., 1834), ESPECIALLY RHINOCHIMAERA AND ITS ALLIES.

BY SAMUEL GARMAN.

WITH FIFTEEN PLATES.

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No. 2. — *The Chimaeroids* (*Chismopnea* Raf., 1815; *Holocephala* Müll., 1834), *especially Rhinochimaera and its Allies.* By SAMUEL GARMAN.

THERE are few of the marine animals that on account of structure and relationships to other forms living and extinct have as great interest for zoölogists and palaeontologists as the Chimaeroids. Their line of descent extends to Devonian times and away beyond and back to a meeting with that of the Plagiostomia near the point at which the latter separated from the bony fishes. That the line has been well traced for a long distance through the fossils only makes it the more interesting. Item after item of information relating to the group has been carefully gathered, discussed, and placed on record, but the advances among the recent have been very slow, and those among the fossils, though in some ways much more extensive, have left much to be desired. The type species of Chimaera and Callorhynchus have been known since the establishment of these genera by Linné and Gronow, in 1754. More recently other species have been added to each of them. A most important addition to the knowledge of the group dates from the capture of the types of the genus Harriotta, by the United States Fish Commission, and their description by Messrs. Goode and Bean, in 1894, and a little later another was made by the discovery of a Japanese species, by Professor Mitsukuri, in 1895, which was placed in the same genus, named but not described. The importance of the species from Japan was not recognized for some years, until Dr. Alexander Agassiz, returning from one of his explorations of the Coral Islands, saw and purchased a second specimen from a dealer in Tokyo. Dissection of this specimen supplies the reason for existence of this paper; it brings to light a number of interesting details concerning Chimaeroids, and some which pertain to other forms than that directly under consideration. The following are among the results and conclusions, brought prominently forward at this moment, that appear to be most worthy of attention.

The species, Rhinochimaera pacifica, is described and figured with details of skeletal and other anatomy.

A new genus, Rhinochimaera, is established, also a new family, Rhinochimaeridae, to contain Rhinochimaera and Harriotta, and still another new family, Callorhynchidae, to include the genus Callorhynchus.

The body of Rhinochimaera is typical of that of most Chimaeroids; the proboscis is an ancestral feature that has become much reduced in Callorhynchus and is obsolescent in Chimaera.

The rostral cartilages are articulated to the skull and are not prolongations of it, as in certain Platosomia, Raiae, or in Antacea, Sharks, on some of which the rostral cartilages resemble a tripod, but with two legs superior, unlike Chimaeroids.

The nearest approach, so far as noted, of recent Chimaeroids to Plagiostomes, as attested by brains, dorsal spines, etc., is made toward Squalus and Heterodontus of the Antacea.

The teeth of Rhinochimaera resemble the embryonic and ancestral more than those of the other recent genera of Chimaeriforms; they are cutters rather than grinders, and probably are most like those of the Myriacanths and Rhyncodonts among the fossils.

In Harriotta the tritors are grouped like the grinders of certain Placodont fishes more than those of other Chimaeroids.

The tritors originated on the horny dental plate through stress or impact, much as the molars of Placodonts and others were originated from the indurated membranes of the jaws, or their hardened papillae.

To judge from the dentition alone, the extinct Myriacanths were nearer the ancestral stem on which farther back the four-toothed forms Rhynchodus and Rhamphodus may likewise be found.

The brain of Rhinochimaera, like its rostrum, is nearer that of Callorhynchus than to that of Chimaera, reduction in the head of the last having brought the hemispheres and the olfactory lobes in contact.

The notochord of Rhinochimaera is provided with rings like that of Chimaera; it is unlike that of Callorhynchus, which shows no rings and is probably the more primitive type.

The males of living Chimaeroids are subject to a certain metamorphosis in acquiring secondary sexual characters as they become mature; a frontal tenaculum and two ventral tenacula are developed as the claspers approach functional maturity.

A more primitive form of the frontal tenaculum is that of the extinct form Squaloraia; in its inception the organ was merely a transverse fold of the skin on the forehead.

The frontal tenaculum, being a sexual character, is not to be homologized with dorsal spines, or with the illicia of the Lophioids, though treated as if of similar nature by early authorities.

The function of the tenacula below the bases of the ventral fins is somewhat like that of the series of erectile hooks on the upper sides of the pectorals of some Platosomia, Raia ocellata, for instance.

The lateral canal systems of Rhinochimaera and Harriotta are made up of pseudotubules, tubes narrowly slit outwardly; that of Callorhynchus consists of tubes, and that of Chimaera is a system of grooves.

The spiral intestine of Rhinochimaera is similar to that of the other living Chimaeroids.

The first dorsal is short, erectile, and has a spine and radials in all members of this group.

The second dorsal is long in the Chimaeridae, of medium length in the Rhinochimaeridae, and short in the Callorhynchidae.

The armature of the supracaudal fin is peculiar to Rhinochimaera.

The claspers of Rhinochimaera and Harriotta resemble one another; except in being simple, they are unlike those of Callorhynchus; in those of the Chimaeridae the cartilages are trifid.

The claspers, intromittent organs, are possessed by both Plagiostomes and Chimaeroids; the tenacula of the latter are peculiar to them.

The position of the clasper of the Chimaeroid is rather above the edge of the ventral; that of the Plagiostome is below it.

Certain peculiarities of the Chimaeroids, especially of skull and brain, are perhaps best accounted for by supposing the group to have been derived primarily from a short-snouted and short-faced form, acquisition of the long snout and the prognathous condition of the skull afterward carrying the olfactory lobes and the hemispheres forward and separating them from the balance of the brain and from one another, and in Chimaera a still later loss of the snout and shortening of the anterior part of the skull bringing the lobes and the hemispheres together into a single mass.

Rhinochimaera pacifica.

Plate 1, Fig. 1.

Hariotta pacifica Mitsukuri, 1895, Zoöl. Mag. Tokyo, VII., without description.
Rhinochimaera pacifica Garman, 1901, Proc. N. E. Zoöl. Club, II., 75.

The specimen here described is a fully developed male of about thirty-six inches in length, before a slight loss from the filamentary extremity of the tail. On account of the figure some of the details of shape need not be dwelt upon in the text. In a general way the form is that of a Chimaera with a long proboscis from the forehead. The amount of compression in the head and body is not very great; the body cavity is included in the anterior half of the total length; the head is massive, rather longer than the abdominal portion of the body, and has a long tapering rostrum which is subtriangular in cross-section, placed pretty well up on the forehead, flattened and provided with special sensory apparatus on the lower side, depressed and slender forward, and pointed at the end; the caudal region occupies half or more of the total length, is compressed and tapers regularly to a filamentary extremity, is encroached upon by the second dorsal fin, is surmounted in part by a low rudimentary fin, the upper edge of which bears an armature, and is subtended by a longer, deeper, and unarmed subcaudal fin. The skin is soft and smooth; there are four vertical fins and two pairs; the anterior dorsal is erectile and has a strong serrated spine and distinct radials. The length of the head is more than one-fourth, the length of the caudal section is about one-half, the length of the snout is little more than one-sixth, the depth is nearly one-tenth, and the width is nearly one-fifteenth of the total length. The oral portion of the head is prominent; the mouth is similar to that of Chimaera. As in the other recent Chimaeroids, there are three pairs of the teeth, one of palatines, one of vomerines and one of mandibulars, Plate **5**, Figures 1 and 2. Mere dot-like points, to be seen under a lens, on the sharp edges of the teeth, are the only approaches to tritors; they have the appearance of the ends of small pores. By comparison of the tongue figured on Plate **12** with those on Plate **5** and Plate **13**, it will be seen that this organ attains a somewhat greater development in the present form. The eye is large and is placed on the side of the head in such position as to command views outward, forward, and upward without hindrance. On the first and the second arches there are five well-developed gillrakers, with several rudiments; they are short, hardly one-sixth as long as the eye, and are acuminate; on the third arch and the fourth all of the rakers are more or less rudimentary. This individual, being a mature male, possesses a frontal tenaculum, armed with about ten series of hooked spines, above the front edge of the orbit on the forehead. The back is nearly straight. The dorsal spine is situated above the bases of the pectorals; it is strong, has a narrow ridge in front, and is smooth on all edges with the exception of slight roughnesses on the hinder angles near the outer end, possible indications of sharp hooks on young individuals. Four rays appear in the first dorsal behind the spine, and a low membrane connects this fin with the second dorsal, which last rises gradually to less than half the height of the first and terminates abruptly more than twice the length of the eye forward from the origin of the upper fin of the tail. The upper caudal fin rises gradually, and, descending even more so, terminates more than twice the length of the orbit forward of the end of the tail, on this specimen. On the upper edge of this fin, which is somewhat rudimentary, there is a peculiar arrangement of small spines, Plate **4**, Figure 2; a pair of larger ones are placed side by side and directed laterally, and behind each pair, between it and the next, there is a couple (1–3) of smaller spines placed longitudinally and pointing upward, forward, or backward. This armature continues to within a short distance in front of the end of the tail, and behind its point of disappearance there is a low ridge to the extremity. The subcaudal fin is much deeper than the supracaudal; it originates below the termination of the second dorsal, rises gradually, becomes deepest in the anterior half of the length, then slowly tapers to the caudal filament. The pectoral fins are long, more than two and one-half times as long as wide, and when extended the sharp outer angle reaches to the bases of the ventrals. The length of the ventral fin is about equal to the height of the first dorsal and the width is less than half of the length; the claspers are simple, slender, nearly four times as long as the eye, subround in trans-section, very muscular near the base, enlarged into an oblong rounded spine-covered bulb at the extremity, and jointed so as to be turned directly forward, Plate **3**, Figures 1, 4 and 5; each ventral tenaculum has three strong hooks on its inner edge. There is no distinct anal fin.

On the sides and the lower surfaces the color is a light olivaceous or plumbeous more or less silvered; toward the back and on the tail it is more brown; the fins are darker to blackish outward.

Total length, 35.5; snout, 6.5; snout to dorsal spine, 10.8; snout to second dorsal fin, 15.4; snout to upper caudal armature, 24.4; snout to vent, 17.2; depth, 3.5; length of pectoral fin, 6 5; length of ventral fin, 3.5; snout to anal, 20; snout to pectoral fin, 10.3; snout to eye, 8.3; length of orbit, 0.8; length of dorsal spine, 3.6; length of clasper, 3.1; width of gill aperture, 1.1; width of body or head, 2.4; length of cephalic tenaculum, 0.6; length of head, 9.5; depth of body at axil of ventral fin, 2.2; width above axil of ventral fin, 1.1; and length of caudal section (probably after a slight loss), 17.5 inches.

Specimen described from Tokyo, Japan. Other specimens are said to have been purchased in the same market that were caught near by, in water of two hundred fathoms or more in depth, off Misaki.

Lateral Canal System, Plate **1**, Figure 1; Plate **2**; Plate **4**, Figure 3.

The structures and functions of these canals are similar in the Chimaeroids and the Plagiostomia. The excessive differentiations of structure and the complexities of function obtaining on some of the deep-sea bony fishes do not occur on either of them. In the distribution of the canals, however, there are certain peculiarities in all the members of the group that distinguish the Chimaeroids from both Plagiostomes and bony fishes. A description of the system on Rhinochimaera applies fairly well to all the genera of its kindred, for even in the strange form of Callorhynchus one has but to apply the foliation of the snout to the lower side of the rostrum to make the similarity at once apparent. For comparisons and for nomenclature see this Bulletin, Vol. XVII., No. 2, Garman, 1888, On the Lateral Canal System of the Plagiostomia and Holocephala, Plates I. to LIII., and Mem. Mus. Comp. Zoöl., Vol. XXIV., Garman, 1899, Deep Sea Fishes, Plates LXIX. to LXXXIV. On the Chimaeroid the aural branch of the system, which crosses the back of the head, lies in front of the orbital, which latter passes down behind the eye, and connects directly with the cranial; this places the short occipital behind the aural, and consequently the orbital does not meet the cranial. On Plagiostomes and on bony fishes the occipital is in front of the aural, and the orbital meets the cranial at some distance in front of the aural. In one case the occipital can be regarded as a portion of the lateral line, in the others it must be considered as a continuation of the cranial branch. On Chimaeroids again, the mouth being forward from the eye, the angular branch passes down and forward from the orbital to meet the narial, but on Plagiostomia having the mouth backward from the eye the angular passes backward. In the Rhinochimaeridae the canals have the appearance of tubes that have been longitudinally slit on the outer side, Plate **4**, Figure 3; they are thus intermediates between the more open grooves of the Chimaeridae, and the tubes of the Callorhynchidae. As is seen on Rhinochimaera, Plate **1**, Figure 1, the jugular meets the orbital, and the angular descends from the orbital and passes downward and toward the front to meet the nasal and the oral; the same is true in Harriotta, Plate **2**, Figure 4. In Chimaera the oral meets the angular, Lat. Canal Syst., Plate II., Figures 3 and 4, but on Callorhynchus it starts from the orbital, l. c., Plates III. and IV., Figure 1. On both Rhinochimaeridae and Callorhynchidae the jugular starts from the orbital; on Chimaeridae it starts either from the angular or the orbital. On the individual from which the description of Rhinochimaera is taken, the aural is not continuous across the head, but is in two parts, which pass one another and overlap for some distance, Plate **2**, Figure 1; the cranials and rostrals pass from the junction of aurals and occipitals forward to the end of the snout, bending toward one another between the eyes; the subrostral lies at the side of the snout and meets the orbital below the middle of the orbit; the occipital passes down and backward from the aural; the orbital goes down and forward from the occipital; and the angular goes down, then bends forward to the oral and the nasal. The jugular meets the orbital, and, like the oral, is more or less broken and disconnected behind the symphysis. On this specimen the narials of the two sides are continuous across the lower side of the snout, forming the only complete connection, except the neural, between the system of the right side and that of the left. On specimens of Harriotta the narials appeared somewhat broken at this point, orals and angulars also were broken, but the aurals were undivided, Plate **2**, Figures 3 and 5. On both Rhinochimaera and Harriotta the line makes some descent backward from aural and cranial to orbital and thence proceeds nearly straight back to a point below the origin of the supracaudal fin, where it turns toward the upper edge of the subcaudal fin and continues along the lower edge of the side on the muscular portion to the end of the tail. The close general correspondence of the lateral systems of these genera is very evident if the figures of Rhinochimaera pacifica, Plate **1**, Figure 1, and Plate **2**, Figures 1 and 2, are placed side by side with those of Harriotta raleighana, Plate **2**, Figures 3 to 5.

The Claspers, Plate **3**, Figures **1**, **4**, **5**.

The claspers of Rhinochimaera are similar in construction to those of Callorhynchus; they differ greatly from those of Chimaera. They have the appearance of being formed of a narrow strip of cartilage rolled into a tube, then twisted so that the joined edges, indicated externally by a shallow groove, are given a complete turn in the length of each clasper. In the distal half each is round, hard, and slender; proximally each is much thickened by the strong muscles that surround its base and include the receptaculum, the opening to which is hardly visible on the outside. At the free end, the tube from the receptaculum opens in the cleft extending from the interior of a small, fleshy, spine-covered bulb. As the claspers lie at rest, the clefts open outward from one another; but when in function the claspers are turned down and forward with a slight rolling motion, Plate **3**, Figure 4, making the clefts to open inward, more toward one another, and the spine-covered surfaces to be carried outward so as not to come in contact. The spines at the extremities are erectile and hook toward the bases of the organs, thus forming effective holders. Turning the claspers down and forward from the body appears to open the mouths of the receptacula and bring them near the openings of the spermatic ducts. For comparison with those of Rhinochimaera the intromittent organs of a skate, Raia laevis, are figured on Plate **4**, Figure 5; they are turned toward the head as in function, without indicating the peculiar structures of the cartilages near the outer ends. The position of the clasper with regard to the ventral fin may be a matter of no great importance, yet it adds to the number of peculiarities distinguishing recent Chimaeroids from the Plagiostomes. The clasper of the Chimaeroid, Plate **3**, Figures 1 and 2, occupies a position above the edge of the ventral fin, in a measure between the fin and the body; that of the Plagiostome (Plate **3**, Figure 3, a young specimen of Carcharinus terraenovae) lies below the edge of the fin, which extends between the clasper and the body.

The Skull, Plate **1**, Fig. 2.

In the skull of Rhinochimaera pacifica there is little or no departure from the general type of Chimaeroid skull. The shapes as outlined, either from above, below, or from the side, may be described in similar terms, and the minor differences are not much greater than are to be seen in the different species of Chimaerae, or even than those obtaining in the different stages of an individual of a species of Callorhynchus. The parietal region is broader than that of Chimaera monstrosa, and narrower than that of Callorhynchus callorhynchus; the frontal region is thicker, wider, and rounder, and does not form a blade-like crest as in Callorhynchus. The facial portion, oral and olfactory section, is more produced than that of Chimaera monstrosa; in this respect it more resembles that of Callorhynchus callorhynchus, in which the narial portion of the skull is much farther forward from the eye than in Chimaera monstrosa, Plate **11**. In the young of Callorhynchus callorhynchus, Plate **10**, and in the young of other Chimaeroids the facial region of the skull is shorter than in the adult.

Whether a distinct rostral prolongation is developed or not, the rostral cartilages are similar in all the genera of recent Chimaeroids. The upper rostral cartilage of Rhinochimaera rests on the frontal crest, about midway from the orbital to the narial section, and has a more robust development than on any other of the known Chimaeroids, Plate **1**, Figure 2. On Chimaera colliei the point of attachment of this cartilage is about the same, but on Chimaera monstrosa, Plate **11**, it is higher on the forehead, and on Callorhynchus callorhynchus it is much nearer the nasal sacs. Though Plate **10** was drawn from a very young specimen, which had not attained the great facial prolongation of individuals of the same species at greater age, it shows the lower rostral cartilages with a proportional development approaching that seen in Rhinochimaera, Plate **1**. As shown on Plate **11**, in Chimaera monstrosa, and in other species of the same genus, the lower or subrostral cartilages are much dwarfed in size, as also is the case with the upper or suprarostral, though in much less degree. The fact that these cartilages are present and so well developed in the species of Chimaera, in the absence of a rostrum, suggests that a rostrum existed in ancestral forms and has become obsolete. The three rostral cartilages are present, in varying degrees of perfection, on each genus of the Chimaeroids. The bases of these cartilages are attached to the skull by ligament in such a way as to admit of considerable movement of the distal extremities up and down. On Chimaera monstrosa, Plate **11**, the suprarostral cartilage presents the appearance of having originally been attached near the nasal capsules, as in Callorhynchus, and of having the basal portion, for a short distance, brought back against and fused with the frontal region of the skull; the ligamentous attachment, however, is at the base of the free portion.

The labial cartilages, present on all the genera, are the same in numbers and positions, but vary greatly in size. They have been worked out in Chimaera and Callorhynchus by Müller. On Rhinochimaera the lower labial cartilages — that is, the larger ones (called by Müller the unterer unpaarer Lippenknorpel in Callorhynchus, but actually paired in this genus as in the other genera) — are smaller than those of Callorhynchus callorhynchus, Plate **10**, and larger than those of Chimaera monstrosa, Plate **11**, said to be absent by Müller. By some authorities the remnants of the intermaxillaries and the maxillaries are to be found in the superior labial cartilages. In all of the genera examined there is a pair of lower labial cartilages. This pair is closely bound together in large specimens of species of Callorhynchus, but in young individuals the two are distinct, and in very young ones of Callorhynchus callorhynchus there appears to be an additional pair of slender bars of cartilage crossing immediately in front of the large ones. These are distinctly shown on Plate **10**; on later stages they have apparently fused with the larger ones behind them. The excessive development of the chin cartilages, the unterer unpaarer Lippenknorpel of Müller, in Callorhynchus is no doubt connected with feeding habits which necessitate grubbing or picking food off the rocks or out of the sands.

Branchial Skeleton, Plates **12**, **13**.

In general the branchial skeleton of Chimaeroids does not reach so great a degree of perfection as that of the Plagiostome. This is especially evident in the basibranchials, copulae, which in all the species of Chimaeroids are more or less undeveloped, some of them being mere lumps of cartilage in the tissues attached but remotely to the hypo- and cerato-branchials. A marked contrast in these respects is to be seen on comparison of the species figured on Plates **12** and **13** with such a shark as Chlamydoselachus anguineus, one of the lowest of its order, possessing the greatest degree of perfection in the branchial skeleton, in which basibranchials and hypobranchials are fully developed and intimately connected. On the other hand, the epibranchials of Chimaeroids are commonly better developed than those of the Plagiostomia.

The branchial cartilages of Rhinochimaera pacifica, Plate **12**, are typical of its entire group. Such differences as there are lie mainly in the inferior connections among the copulae. With exception of the hindmost one, the basibranchial copulae are more remotely connected with the hypobranchials than is the case in the sharks; they are rounded lumps or disks of cartilage which do not form close articulations. In the branchial cartilages of this species, Plate **12**, the three copulae between the first basibranchial and the fifth are represented by two pairs of small lumps of cartilage and a larger odd one, the connections of all of which are ligamentous and remote. The glossohyal is wedge-shaped and does not entirely separate the basihyals, as in case of Callorhynchus callorhynchus, Plate **13**, Figure 3; it differs also from that species in that it is produced forward into the tongue. The hindmost copula is broad anteriorly; in the posterior third it tapers to a sharp point; it is shaped much like that of species of Chimaera, Plate **13**, Figures 1 and 2, and is not so narrow and slender as that of Callorhynchus on the same plate, Figure 3. Apparently there is considerable individual variation to be considered in connection with all the Chimaeroids, especially in regard to the basibranchials. The first two and the last one of the copulae appear to be regularly present, but between these there are a couple which in cases are present as pairs, in others as single lumps. Instead of the single copular lumps present in Callorhynchus callorhynchus, Rhinochimaera pacifica has two pairs, Chimaera monstrosa has a pair and a single large shield preceded by a small pair, and Chimaera colliei has a pair and a single large shield followed by a pair, while the shield or lump preceding the hindmost has a pair of small cartilages in front of it and another pair behind it, Plate **13**, Figure 2. Among other variations obtaining among the species, that of the glossohyal is noted in connection with the tongue, and those of the epibranchials from elongate and narrow in Rhinochimaera, Plate **12**, Figure 2, to short and broad in Callorhynchus callorhynchus, Plate **13**, Figure 3, are readily to be seen on examination of the mentioned figures.

Tongue, Plates **12** and **13**.

The tongue of Rhinochimaera is larger than that of either of the other species dissected; it is prominent, free from the floor of the mouth, and is well supported by a forward prolongation of the glossohyal cartilage. At the forward extremity it is truncate; the upper surfaces are covered with papillae, Plate **12**. In both of the species of Chimaera dissected the tongue is seen to be much smaller, sharper in front, and to have much less of the glossohyal within it, Plate **13**, Figures 1 and 2. The tongue of Callorhynchus callorhynchus, Plate **13**, Figure 3, is greatly reduced or quite rudimentary, and the glossohyal is not produced into it as in the other forms described. From the shape of the tongue of Harriotta raleighana, it is evident that the glossohyal is produced into it; the skin of the organ is peculiarly thickened and folded on its upper surface, Plate **5**, Figure 5, a consequence probably of rough contact and severe pressure by the hard portions of the food that has established the tritors on the teeth. The tongue of Harriotta is markedly different on the surface from that of either of the other genera, as is sufficiently obvious on comparison with the tongues figured on Plates **12** and **13**, all of which are furnished with numerous papillae.

Teeth, Plates **5**, **6**, **7**.

In all the known recent Chimaeroids the individual possesses three pairs of teeth, vomerines, palatines, and mandibulars, one pair of each; that is, two pairs of upper and one pair of lower teeth. Some of the fossil forms appear to have had a greater number, and some of the earliest of the extinct types apparently had a single pair of lower opposed to a single pair of upper teeth. Rhynchodus of the Corniferous and Hamilton limestones, Devonian, described by Newberry from Ohio, is said to be limited to the two pairs, vomerines and mandibulars, so also is Rhamphodus of Jaekel, from the Upper Devonian. These genera are of some interest in connection with this writing because their tooth-characters are in certain respects similar to those of Rhinochimaera, which among recent species possesses the most primitive features of dentition. Of living forms the resemblances in the outlines of the teeth are closer than in their details of structure. While the differences in these last are excessive, they are so distributed among the genera most closely allied in regard to other peculiarities as to prevent use in distinguishing higher groups. This is well illustrated by the teeth of Rhinochimaera and Harriotta, members of a single family, Plate **5**, — instances respectively of the least differentiated and the most specialized in dental structures. An abundance of fossil Chimaeroid teeth suggests that they may have been shed at times by individuals as in Plagiostomia. While a periodical shedding of teeth might be expected from what obtains in other forms, we have as yet no evidence of its existence. The worn condition of the teeth in all specimens at hand points rather toward a continuous growth from the nourishing tissues and a continuous grinding away on the side toward the mouth cavity.

The mouth of Rhinochimaera is narrower and more pointed than that of its fellows, probably in these respects approaching that of Rhynchodus, or of Rhamphodus, consequently its teeth are narrower and more elongate, Plate **5**, Figures 1 and 2. Altogether the mouth resembles in a measure the beak of a bird of prey; the teeth pass one another like the edges of a pair of shears and in front the vomerines are turned downward in a sharp hook. As the teeth are used entirely for cutting and holding and not for crushing, the stress comes on the sharp edges. The unassisted eye may hardly detect the existence of tritors, but with a lens, where the edges have been somewhat worn away, a series of the extremities of minute calcigerous tubes or pores is to be recognized. The dental plates are thin; in appearance they recall the horny fin rays, though they are not fibrous and are much harder and more brittle. The vomerines are small, convex outwardly, concave inwardly, in contact forward, hooked downward in front of the lower jaws, and feebly notched on the lateral cutting edge by contact with the mandibulars. The palatines are not in contact on the median line of the mouth; each of the pair is long and narrow, concave on the lower surface, blunt on the inner angle, slender and acute posteriorly, straight on the cutting edge except at the forward extremity where it curves upward, and but little bent upward on the inner edge. The mandibulars are longer, more slender, and more pointed than the palatines; they are concave on their upper surfaces, rounded instead of angled inwardly, slightly in contact at the symphysis, very little bent downward at the inner edges, and straight on the cutting edges except when curving down and inward below the vomerines. The only tritoral areas on these teeth are on the cutting edges. Probably the teeth of Rhinochimaera do not vary greatly from the type possessed by the ancestral Chimaeroid, and no doubt the changes undergone in the teeth from very young to adult stages are comparatively slight. The indicated food of this Chimaeroid is crustacean and other life, of considerable depths of the ocean, in which the skeletons have no great degree of hardness.

Harriotta, in most respects the nearest ally of Rhinochimaera, differs radically in regard to the teeth, Plate **5**, Figures 3, 4, 6–9. The dental plates are similar in shape and alike in number, but the tritors, even though they owe their existence to the common causes, stress and impact without perceptible differences in regard to exertion or reception, differ in arrangement from those of any other known Chimaeroid either fossil or recent. The mouth being wider in this genus than in Rhinochimaera and the function depending on the side of the tooth, rather than on the edge, the teeth are broader and much less sharpened at their extremities. The vomerines are of moderate size, somewhat broad, convex outward, concave inward, slightly hooked down in front of the mandibulars, and bear a marginal series of small tritors about nine in number. They are in contact forward, and rather widely separated backward on the median line. The palatines are broad, broadly rounded in front and at the inner angle, more or less sharp posteriorly, and bear more or less of a prominence, due to the median series of tritors, on the hinder margin. The tritors with some irregularity are distributed in four rows: an outer series at the edge of the tooth of about six rounded tritors, an inner series of about three near the front end, a median series of several parallel with the inner, and a posterior series of about nine broad, short, closely placed tritors extending from the hind margin forward over more than half of the tooth and to some extent resembling the dental series of certain Myliobatidae. The mandibulars are pointed at each end and convexly curved on both outer and inner margins; they bear an outer series of small rounded tritors anteriorly, along about two-thirds of the edge of the tooth, and a median or posterior series of broad, short, closely packed tritors in the hinder three-fifths of the tooth, extending to the hind margin, but not to the posterior extremity. The description immediately foregoing is taken from a specimen that had almost reached maturity, and may be said to fairly represent conditions in an adult, Plate **5**, Figures 3 and 4. The appearance of the teeth in a half-grown specimen are indicated on Plate **5**, Figures 6 and 7. Of such immature specimens the teeth are farther apart and on each tooth the angles are less developed. The tritors also are farther apart and much smaller, some of the hindmost of the wide ones of the inner series being very faintly indicated or altogether absent. Each of the teeth at this stage may be described as shorter, broader, and less angular than the corresponding tooth of the adult. In quite young specimens, such as that of which the teeth are figured on the same plate, Figures 8 and 9, the teeth are less broad and more angular and tritors have not appeared. This in all likelihood represents the condition obtaining in the adult of some ancestor; and this stage is nearer to the permanent type in Rhinochimaera. While there are no tritors on these teeth the positions they finally occupy are already indicated by slight ridges or swellings. A still earlier stage would probably bear teeth on which these ridges would not be developed.

The teeth of very young Callorhynchidae, Plate **6**, Figures 3 and 4, before the tritors appear, are similar to those of a like stage in the Rhinochimaeridae, as represented by Harriotta, Plate **5**, Figures 8 and 9. In later stages the tritors appear on the ridges of palatines and mandibulars and on the cutting edges of the vomerines. This condition appears to be retained by the adult in the type here identified with Callorhynchus smythii Benn., of which the teeth are shown on Plate **6**, Figures 1 and 2. In the other species of the genus, however, the hinder portions of the tritors of the palatine teeth enlarge and fuse, while the forward portions remain as two prongs that may apparently become less extensive toward the front; at the same time the tritor of each mandibular tooth shortens and broadens until in cases somewhat angular or nearly round, as in Callorhynchus milii, Plate **7**, Figures 7 and 8. If in addition to the individual variations those shown to occur in the five species of this genus at hand are also considered, we get a hint of what may be expected among other genera, recent or extinct. Teeth from the various stages of individuals, or of the different species detached and described, as is necessarily done with fossils, might readily lead to multiplication of synonyms for both species and genera. Three of the known living species are reported from the southwestern coasts of South America; the other two are from Tasmania and the Cape of Good Hope respectively. The younger stages of all are similar. Callorhynchus callorhynchus, Plate 7, Figures 7 to 9, is the species most widely known; in it the tritor of each palatine tooth occupies the greater part of the entire length of the dental plate and sends forward two prongs, the inner of the two being the longer. C. smythii, Plate 6, Figures 1 to 4, as already mentioned, has two distinct parallel tritors on each of the palatine teeth. Both of these forms occur at Valparaiso and Talcahuano. C. tritoris is a new species from the Mejillones; one of its palatines and the vomerines are drawn on Plate 6, Figure 9, where the tritor of the first is seen to be placed far back on the tooth, to be broader than long and hardly notched anteriorly. In C. milii, Plate 6, Figures 7 and 8, the prongs are short; and the tritors have a considerable forward extension on the palatine teeth, while the mandibular tritor is short, rounded, or oblong, and like those of the palatines situated near the posterior edge of the tooth. This is the Tasmanian species first named, described, and figured by Bory, 1823, and later described by Richardson, 1841, under the name C. tasmanius. Callorhynchus capensis, Plate 6, Figures 5 and 6, is marked by very slender and sharp forward extensions of the tritors on both palatine and mandibular teeth; these prongs are elongate and tapering, and the hinder portion of the tritor on the palatine is comparatively short, but on the mandibular teeth the posterior swollen portion of the tritor appears to be longer than that of the tooth above it. This species was described by Duméril, 1865, from specimens secured at the Cape of Good Hope; the figures cited above were drawn from an individual sent by E. L. Layard, Esq., from the same locality. Interest in C. capensis is heightened by the fact that traces of its existence have been found in Cretaceous formations and in a locality which greatly widens its distribution. For the species described by Newton, 1876, in the Quarterly Journal of the Geological Society, p. 326, Vol. 3, and figured and described by the same author, 1878, in the Memoirs of the Geological Survey of the United Kingdom, IV., p. 41, Plate XII., Figures 11 and 12, under the name Callorhynchus hectori, from a fossil palatine tooth found at Amuri Bluff, New Zealand, in a fine conglomerate, believed to be of the age of the Lower Greensand, of the Cretaceous, is not to be separated from C. capensis by any of the characters at present known. This is the earliest positive evidence of the existence of a species of now living Chimaeroid.

The teeth of Chimaerae are more differentiated than those of any other genus of the group. Judging from the dentition, the evolution of Chimaera, as in the reduction of the rostrum, would appear to have gone a stage farther than that of the species of Callorhynchus, and in doing this to have acquired the peculiar laminated structure and the palatine and mandibular tritors on the forward edges of the teeth. The ridges on the inner sides of these teeth may be looked upon as remains of tritors, similar to those of Callorhynchus smythii, Plate 6, Figures 1 and 2. If the rise of Chimaera were to be traced, there would probably be found among its ancestors some with teeth like those of the very young Callorhynchi, and others of a later period in which tritors, like those of Callorhynchus smythii, were present on the sides of the teeth, and yet others, still later, in which by change of feeding habits the impact had been changed to the front edges of the palatine and the mandibular teeth, where the stress or impact is generally exerted, and where tritors now are in all except very early stages of Chimaera. No better way at present suggests itself to account for the differences in dental structure found in Chimaera and Callorhynchus. On Plate **7**, Figures 1 to 3, the much-worn teeth of an old individual of Chimaera monstrosa are drawn. If the palatine and the mandibular teeth of this species are compared with the same teeth of Callorhynchus smythii, or of the very young of the other species of that genus, or even of the very young of Harriotta, it will be seen that the two lateral ridges of each palatine and the single lateral ridge of each mandibular are in the same positions, but in the later stages of individuals of Chimaera the impact is applied to the forward extremities of the ridges, and in the other genera mentioned it is exerted on their sides. Yet if the account of the dentition of Chimaera is carried no further it will be incomplete and misleading, for as the anterior edges and tritors of the palatine and mandibular plates are ground away by use in aged individuals, the impact is more and more applied to the inner sides of these plates, farther and farther backward. Consequently tritors develop, later in the lives of such individuals, on the sides of calcigerous tubes the extremities of which were the tritors of earlier stages. On the teeth, of a specimen of Chimaera monstrosa more than thirty inches in length, shown on Plate **7**, Figures 1–3, the tritors of the forward edges are the only ones that appear; the ridges of the inner sides are present, but evidently they had not served as grinders and they bear no tritors. On old individuals of Chimaera colliei the tritors of these ridges are prominent and more swollen than those of Callorhynchus smythii, Plate **6**, Figures 1 and 2, and possibly in this or other species of Chimaera they may with greater use become much expanded, or even may become confluent somewhat as in most species of Callorhynchus.

The Viscera. Plate **1**, Figure 2; Plate **4**, Figure 4; Plates **8** and **9**.

The stomach and the inside walls of the body cavity of Rhinochimaera pacifica are blackish; behind the stomach the intestines are lighter in color. The alimentary canal is but little longer than the abdominal cavity; the extent of the difference in the two lengths is indicated in the short transverse portion of the valvular section of the intestine in Plate **1**, Figure **2**. The distinctions between the stomach and the intestine are not particularly well marked, though the walls of the former are darker and are provided on the inside with longitudinal folds or striae, less noticeable when distended, which disappear at the pylorus. The intestine properly so called may be divided into two sections; a longer one containing the first turn of the spiral fold, which originates close behind the stomach at the point of the entrance of the bile duct and as a mere fold of the inner membranes, attached to the wall, gradually makes the turn as it extends backward to the first valve ; and a shorter one beginning at the valve and containing two other valvular constrictions which respectively end the second and the third turns, included between the first valve and the third. On Plate **8**, the intestine is slit open from the pyloric end of the stomach to the vent to show the long, spiral fold, the three muscular and valvular constrictions, and the two short spirals. The portion of the intestine occupied by the longest spiral is more than twice as long as that occupied by the two short ones. The diagrammatic figure 4 of Plate **4**, by means of a dotted line, traces the course taken by the food from the pylorus to the cloaca. The intestines of Callorhynchus callorhynchus, Plate **10**, are in most respects similar to those of Rhinochimaera. The numerous points of resemblance common to those of Chimaera are quite as readily seen. Professor T. J. Parker, 1880, gives a good figure of the spiral folds of Chimaera monstrosa, and describes this portion of the canal in these words, "I found a valve of only three and a half turns, remarkable from the fact that the attached edge did not form a regular spiral, but for a part of its course (namely, during the first turn) formed a slightly sinuous antero-posterior line. In consequence of this, the second compartment of the intestine was fully half as long again as the bursa entiana."

The pancreas of Rhinochimaera is small and elongate; in Figure 2 of Plate **1**, it lies above the intestine immediately behind the left lobe of the liver. As it appeared in the specimen, it was bent backward upon itself, though it may be that normally it is nearly straight. Apparently the spleen is closely bound with it. Above the pancreas, in the figure, and somewhat forward, lies the left testicle, from which the seminal tubes are traced back to the seminal vesicle immediately below the enlarged and lobed hinder extremity of the kidney. The reticulated seminal vesicle, the lobulated kidney, the disk-like testicle, and the complex of seminal ducts are shown more distinctly on Plate **8**. A lower view of these organs appears on Plate **9**, Figure 2, in which the reticulation of the vesicle is not seen.

The liver is drawn in Figure 1 of Plate **9**. It has three lobes, the right one of which is much the longer and is notched at the tip. The gall bladder lies at the right side of the stomach and its duct enters the intestine close behind the stomach at the forward extremity of the spiral fold.

In the bulbus of the heart, Plate **9**, Figure 3, there are two rows of valves, the anterior of which contains three valves, the posterior four, Plate **9**, Figure 4.

Generally the visceral features of Rhinochimaera are in close correspondence with those of the other genera of the group. And this is quite as true of the internal sexual organs as of other internal organs, contrary to what might perhaps have been expected from the great external differences in the claspers. To fully establish this, one has but to compare the present figures of Rhinochimaera with those of the sexual organs of Chimaera monstrosa published by Hyrtl, 1854.

The Brain, Plates **14**, **15**.

The brain of recent Chimaeroids is crowded together posteriorly. The optic and inferior lobes are close to the medulla oblongata and are below the cerebellum. The hemispheres are remote from the optic and inferior lobes, and the connections with them are slender and nerve-like. This shape of the brain, the massing that has taken place backward with the remoteness that obtains forward, is characteristic of the group, so far as known living genera are concerned. A similar crowding of parts of the brain is common among Plagiostomes, but the wide separation of the hemispheres from the optic lobes is peculiar to Chimaeroids. In some genera of the latter the olfactory bulbs are distant from the hemispheres, so also in particular Plagiostomia, but in one genus each hemisphere is closely connected with an olfactory bulb. In these cases either remoteness or the absence of separation of the olfactories serves to distinguish the genera.

The brain of Rhinochimaera pacifica, Plate **14**, from the medulla oblongata forward to the optic lobes differs comparatively little from that of its allies. The posterior mass is similar in shape and in the positions of its component parts. Compared with Chimaera colliei, Plate **15**, Figures 1 and 2, or Callorhynchus milii, Figures 4 and 5 of the same plate, the brain of the present specimen is somewhat smaller in the cerebellum, which does not cover the optic lobes so completely as in the other cases; this deficiency in size, however, may be a feature of the individual and not a character of the species. The nerve-like connections with the hemispheres are more slender in Rhinochimaera than is the case in the other genera. In the distance between hemispheres and olfactory bulbs Rhinochimaera pacifica agrees with Callorhynchus milii, Plate **15**, Figures 4 and 5, though the connections are even more slender than in the latter species and the olfactory bulbs are smaller. Between the hemispheres and the olfactory bulbs in Rhinochimaera the distance is about twice that between the hemispheres and the optic lobes; in Chimaera colliei the distance between olfactories and hemispheres has vanished, while that between the latter and the optic lobes remains. Similar comparisons may be made with the brain of Chimaera monstrosa, which has been worked out by Dr. Wilder and others.

Miscellaneous.

The first mention of the species described above, and a full-grown male of which is figured on Plate **1**, in one-third of its life size, was published by Professor K. Mitsukuri in the Tokyo "Zoölogical Magazine," No. 80, Vol. VII., June, 1895, with an outline sketch on Plate 16 of the same volume. The more important portion of this notice, containing all the description, is reprinted below. By some mistake the outlines were said to be those of a male; they are evidently those of a female. Professor Mitsukuri's remarks are given in his own words: —

"The specimen (male) was bought in the Tōkyō market and is marked as from *Kurihama, Province of Sagami;* there can be no doubt that fishermen of that village caught it in the deep waters (two hundred fathoms or more) contiguous to Misaki. Its unique characters had long been noted by us.

"Unfortunately, I am not yet in possession of the original description of *Hariotta raleighana* by Messrs. Goode and Bean. But the short description, 'the extremely elongate muzzle and the feeble claspers' as well as the comparison of the two figures leave no doubt in my own mind that the two individuals figured belong to the same genus.

"There can also be very little question that they belong to different species. (1) The general shape of the body, (2) the shape and size of the pectoral and ventral fins, (3) the point to which these fins reach when laid back, (4) the shape and disposition of the dorsal fins, (5) distribution of the lateral-line sense-system all seem to point to the specific distinction of the Atlantic and Pacific specimens. The name *Hariotta pacifica* will be most appropriate to the Japanese species."

It would be a matter of some difficulty from this notice, or from the outlines accompanying it, to make a satisfactory identification; it was only by comparison with the type that it might be done. No other description had been published when the specimen of which the present writing treats was brought by Dr. Agassiz from Tokyo. This specimen was dissected from one side and drawings and descriptions were made from the preparations. In the second volume of the Proceedings of the New England Zoölogical Club, page 75, a short preliminary to the present paper was published, in 1901, under the title "Genera and Families of the Chimaeroids," in which it was shown that Professor Mitsukuri's species did not belong to the genus Harriotta, known from the Atlantic, that it represented a new genus, which was then characterized and named Rhinochimaera, and that it with Harriotta constituted a new family, the Rhinochimaeridae, of equal rank with the Chimaeridae and the Callorhynchidae, the last also a new family. The genera and the families were briefly characterized in the preliminary; the characterizations, of greater length and slightly modified by the anatomical studies, are repeated in the present paper. One question raised by the subsequent studies relates to the presence or absence of tritors in Rhinochimaera. On teeth the cutting edges of which have not been worn with hard usage no tritors are visible; but if the extremities of the minute calcigerous tubes to be seen with a lens on the cutting edges of worn teeth are to be accepted as tritors, it is incorrect to say Rhinochimaera has no tritors. Besides the possession of several series of molar-like tritors, the structure of the proboscis in Harriotta, depressed instead of compressed, is a very patent distinction. It was stated in the preliminary that the frontal tenaculum is present on the males of Harriotta, as on males of Rhinochimaera, Chimaera, and Callorhynchus, a fact which was denied in the original diagnosis of that genus. It was added that the frontal tenaculum is only acquired by the young male somewhat late in his existence, about the time he becomes sexually mature and the intromittent "claspers" have approached functional maturity, the advent of the tenaculum coinciding nearly with the beginning of its period of utility in the congress of the sexes. This was in relation to all the genera of the group. It was overlooked at the time that Günther, in 1887, had reached a similar conclusion in regard to Chimaera. The following is a repetition of his statement.

> "The development of the prehensile organ on the upper part of the snout, which is peculiar to the male sex in *Chimaera*, keeps pace with that of the claspers. This organ is visible in our youngest specimen, which evidently was hatched only a few days, as a narrow cartilage of whitish colour entirely covered by the skin, but visible through it. It has not made as great progress in the largest of the young specimens, and therefore does not seem to become detached from the head before the individual attains to sexual maturity."

"Detached from the head" in this may mean either detached from the skull, or attains to partial freedom above the skin, probably the latter.

The frontal tenaculum of the Chimaeroid male is not a modification of a fin ray, as in the Pediculati, but is an accessory sexual organ, in its inception in all probability merely a transverse fold of the skin of the forehead. If it were a modification of a fin spine or radial, it would at the first appear as such, without waiting for sexual maturity, and the embryo would be likely to exhibit traces of its evolution. The frontal tenaculum of Squaloraia, a fossil from the Lower Lias, is to be regarded as an intermediate form between the primary transverse fold and the much-differentiated frontal tenacula of the living Chimaeroids. In the fossil the base of the organ is transverse, and without the simple elongate slender distal portion would sufficiently resemble a transverse fold.

Naturally the higher groups are less clearly outlined in the fossil forms than in the recent, and the farther back attempts are made to distinguish them, along the converging lines to a common ancestry, the less definite the distinctions, until among the earlier they may not be recognized, and the more prominent and numerous the intergradations. The modern tendency of emphasizing divergent features leads to multiplication in the number of families. Woodward, 1891, in the Catalogue of Fossils in the British Museum, Vol. II., distributes the Chimaeroids in four families, Ptyctodontidae, Squaloraiidae, Myriacanthidae, and Chimaeridae. Only the last of these contained species that are now living. If the recent forms are arranged in three families, as in the present writing and in the preliminary, Rhinochimaeridae, Callorhynchidae, and Chimaeridae, the known fossil species will be distributed in five families, by leaving Chimaera pliocenica and C. javana in the Chimaeridae, and placing Callorhynchus hectori in the Callorhynchidae. Undoubtedly future studies will increase the number of families to which even the known fossils are credited. Not much can be done in comparing the recent with the extinct forms, since so little is known of the latter. In most cases the fact of existence has been established only through remnants of the dental apparatus. Of the characterized families the Ptyctodontidae are distinguished by two pairs of teeth, one above and one below, and no spines are known; the Squaloraiidae have two pairs of teeth above and one pair below, like recent members of the group, but the dorsal spine is absent, the body is depressed, and the frontal tenaculum of the male is elongate styliform, much as the proboscis itself; and the Myriacanthidae have the dorsal spine, have dermal plates on the head, and have two pairs of teeth above and one pair and a single symphyseal tooth below.

A number of features are possessed in common by the living forms, features by which they are closely linked together and by which they are readily distinguished from their nearest allies of the Plagiostomia. The form of body or the general shape, the mandibular suspensorium, the teeth, the lateral system, the lack of shagreen, the erectile first dorsal, the frontal tenaculum, and the ventral tenacula of the males, the wide separation of hemispheres and optic lobes of the brain, the articulation of rostral cartilages; these go to distinguish the Chismopnea from the Plagiostomia. For family characters dependence is placed on the differences in regard to the proboscis, on differences in the structure of the notochord, on differences in the claspers, and on differences in the brain and in the lateral line. The generic and the specific separations are made by differences in the details of tritoral development, by the slighter variations in forms of rostra, or in the structure of claspers, by minor differences in the distribution of the lateral line, in the lengths and shapes of the fins, in colors, etc.

The partial descriptions given below are introduced not as redescriptions but as additions to knowledge of several species, rare or not easily secured, to which references have been made in this paper. The lists of genera and species recognized herein are given under the classification.

Harriotta raleighana.

Plate 2, Figs. 3–5; Plate 4, Fig. 1; Plate 5, Figs. 3–9.

Harriotta raleighana Goode and Bean, 1894, Proc. U. S. Mus., xvii. 472, Plate XIX. Figs. 1–4.

The authorities of the United States National Museum have kindly permitted examination of some of the types from which this genus and species were originally described. In consequence it is possible to add some items to the data already published. Necessarily they are limited to external features, as the specimens could not be dissected.

Specimen 35631, from the North Atlantic (Lat. 39° 12′ N.; Lon. 72° 3′ 30″ W.), at a depth of seven hundred and seven fathoms, is the original of Figs. 1 and 2 on Plate XIX. of Vol. xvii. of the Proceedings of the National Museum, 1894, or of Figs. 37 and 38 on Plate XI. of the Oceanic Ichthyology; it has the following measurements: Total length, 15.5, head, 3.5, snout to vent, 6.5, and snout to mouth, 2.5 inches. The individual is an immature male, too young to have acquired the frontal tenaculum, the ventral tenacula, or the functional development of the claspers. Its teeth are represented by Figs. 6 and 7 on Plate **5** of the present work. In number of plates and their general outlines these teeth are somewhat like those of a young Chimaera, but in regard to the tritoral surfaces they are very different. On the palatine and the mandibular teeth there are prominent series of tritors, like small rounded molars; on each of the palatines a series appears, the next to the outer, in which the tritors from the third counting backward are broadened into transverse bars, or in which two small tritors, or more, have united into one broad one. On each palatine tooth there are four more or less complete series of the tritors, the outer two or three of which are extended farthest backward. On the outer edge of each mandibular tooth there is a series of about ten of the tritors or cusps, and from the sixth and the seventh two shorter series extend back nearly parallel with the inner edge of the tooth. The vomerine teeth resemble in outline those of Chimaera. Medially in front each hooks downward in a sharp point; laterally from the point the edge lies higher and has three rounded tritors, the hindmost of which forms the hinder edge of the tooth. The claspers are but partially developed; they are short, without spines, stout and muscular at the bases, and in the distal three fifths of the length are slender, cylindrical, and rounded. The groove is distinct to the end. The positions of the ventral tenacula are indicated by the openings, but within the tenacular cavities the organs are quite undeveloped; the spines, of course, are entirely absent. The frontal tenaculum, being of later development than the claspers, is not yet differentiated. Though there appears to be nothing on the sides of the forehead of this individual to distinguish it from a female, if looked at from above the shape of the tenaculum appears to be faintly outlined beneath the skin in its proper position. The dorsal spine has a sharp compressed keel on its front edge; it is triangular in a cross-section; each of the hinder edges turns directly outward at the side, is sharp, and is barbed by sharp teeth hooking toward the base of the spine. At each side of the postorbital space on the crown there are three or four spines in irregular series, and there are four in longitudinal series at each side of the anterior portion of the base of the second dorsal. The upper margin of the third dorsal is like the others and has no such armature as that of Rhinochimaera pacifica (Plate **4**, Fig. 2).

The lateral line system resembles that figured on Plate **2**, Figs. 3–5, from specimen 39415, but shows individual variation in several points. The upper rostral tract meets the lower at a short distance behind the tip of the snout; they pass into one another at each side of the rostrum. Behind the transverse band of sensory papillae or villi, on the left side of the lower surface of the snout the subrostral line extends back between the suborbital and the prenarial, but does not join with the latter like its fellow of the other side, and the prenarial does not curve out to meet it. Behind the mouth on the chin the line is broken into dashes instead of being entire and transverse; similarly on the throat the transverse line is broken more or less, and is discontinued for a short distance about the middle. Below the middle of the supracaudal fin the lateral line suddenly drops to the lower edge of the muscular portion of the tail where it continues to the end. The line is similar in structure to that of Rhinochimaera pacifica, as figured on Plate **4**, Fig. 3; it is an open groove with closely-set ribs, which do not quite meet over the cavity. The aural portion of the line bends forward at each side from the lateral, and passing inward turns sharply back to meet its fellow in an acute angle, with the apex backward, from which a short line is extended farther backward toward the dorsal spine.

Specimen 39415 of the National Museum is a female, taken in north latitude 39° 44′ 30″ and west longitude 70° 30′ 45″ at a depth of 1081 fathoms. Its measurements are: total length, 25; length of head, 6; length of snout to mouth, 4; snout to vent, 10.5; snout to dorsal spine, 6.5; snout to anal, 14.25; snout to end of second dorsal, 14.25; length of dorsal spine, 2.75; length of pectoral fin without base, 4.5; length of ventral fin, 2; depth of body between dorsals, 2.75; width of pectoral, 2.75; width of ventral, 1.5; depth of tail, 1.4; width of proboscis, 1.1; depth of orbit, 0.56; length of orbit, 0.75; and length from snout to beginning of the upper fin on the tail, 14.9 inches. The dorsal spine has sharp retrorse denticles on both of the hinder edges, and it has longitudinal striations along its sides. It has a smooth, rather sharp ridge in front, and close behind this in a transverse section it is concave and then slightly convex. The spine has a more prominent anterior ridge and more distinct denticles than on the young, but it is stouter in proportion to the fin on the latter. The tongue is subtriangular, Plate **5**, Figure 5, and it has a peculiar structure, induced by feeding habits in connection with which its most important function may be performed in sorting out the softer tissues from the harder portions or broken shells of the prey. The teeth show a considerable advance from what obtains on 35631, as shown in Plate **5**, Figures 6 and 7. In the outlines the hindmost angles are sharper, from extension backward on the edge of the jaw, and the tritors are broader, longer, and closer together, Plate **5**, Figures 3 and 4. They have expanded until those posteriorly on the median ridge have come to resemble the dental cards of species of Myliobatis to which they suggest a similarity also in feeding habits. Possibly the tritors coalesce and their dividing lines become obliterated in greater ages, for this would be in line with the development traced through 35520 and 35631 to the present specimen; in one the tritors are merely suggested, in another they are well grown but separated, and in still another they are much enlarged and in contact, Plate **5**, Figures 3–9. Each of the vomerine teeth hooks downward in front and has 9 or 10 tritors on its cutting edge. There are three series of tritors on each palatine and but two on each mandibular tooth, Plate **5**, Figures 3 and 4; in this they differ from what obtains on the teeth of 35631, Plate **5**, Figures 6 and 7, a difference which may be due to coalescence of tritors on the older individual.

Number 35520 of the National Museum collection is a young male of about 4.1 inches in length; it was captured at a depth of 991 fathoms in north latitude 39° 37′ 45″ and west longitude 71° 18′ 45″. The specimen was secured near the time of extrusion from the eggshell, and so marks a depth at which the eggs are laid. It is the type from which Figures 3 and 4 of Plate XIX. in the Proceedings of the U. S. National Museum for 1894, and Figures 39 and 40 of the Oceanic Ichthyology were drawn. Apparently it has lost the tip of the snout and the caudal filament. The lower fin of the tail is rather indistinct anteriorly, but evidently it originates some distance farther forward than the upper. Probably the specimen was torn from the egg and mutilated in the dredge. The claspers and the tenacula are undeveloped. The parietal spines and those between the dorsals and between the second dorsal and the fin on the tail are quite prominent. They rise above the level of the head and of the dorsal fins and the dorsal spine, as these last are closely applied to the back ; their function appears to be aid in escape from the eggshell and to protect the back and fins at the time and later. The teeth of this individual are figured on Plate **5**, Figures 8 and 9, in four times natural length. They exhibit slight differences in outline from those of older specimens, the principal one of which is a backward extension from the median ridges of palatines and mandibulars; a marked distinction also occurs in the apparent lack of tritors. On each of both palatines and mandibulars there is a symphyseal, a median, and an outer ridge extending to the hind edge of the tooth. Close examination discloses, even in this comparatively undeveloped stage, indications of the molar-like tritors in these ridges, in positions similar to those shown in Figures 6 and 7 of Plate **5**. In each case the inner ridge is formed by the incurved edge of the tooth. The vomerine teeth are less hooked than those on the older specimens, and the tritors are hardly visible.

Callorhynchus milii.

Plate 6, Figures 7, 8; Plate 15, Figures 4, 5.

Callorhynchus milii Bory, 1823, Dict. class. d'Hist. Nat., III., 62, pl. v.
Callorhynchus tasmanius Rich., 1841, Trans. Zoöl. Soc. Lond., III. 174.

A specimen belonging to this species, sent by Mr. W. Robertson from Hobart Town, has a total length of 16.5, a length of head of 4, a length from snout to dorsal spine or to base of pectoral of 4.25, from snout to ventral of 7.4 and to second dorsal of 7.75, a depth of body of 2.5, a length of dorsal spine of 2.75, a length of pectoral of 4, a length of base of second dorsal of 3, a distance from origin of supracaudal to end of base of anal of 0.6, and a length of caudal of 4.75 inches.

The form is compressed, and is massive about the head ; seen from the side the outline is very convex and prominent above the front edge of the eye and forward for a short distance. The foliate extremity of the proboscis is broadest near the hind margin, where it is subtruncate and slightly notched. The dorsal spine is situated above the origin of the pectoral ; it is compressed and sharp in front. In a trans-section it is concave immediately behind the sharp front edge, then becomes convex ; the posterior edges have sharp retrorse serrations. The pectoral reaches behind the origin of the second dorsal, and behind the bases of the ventrals, which last extend little farther backward than the origin of the second dorsal. Hinder margin of ventral and upper margin of second dorsal concave. Base of anal short, close to subcaudal, with which its base is united by a membrane; anal depth about equal to height of second dorsal. The bases of the anal and the subcaudal of this specimen are about a quarter of an inch apart, excepting the membrane, yet when the anal is at rest its hind border is in contact with nearly the whole anterior edge of the fin behind it. The color of the flanks is silver, of the back is light brownish, and of the fins is brown. Probably the colors vary with age and sex.

On a specimen of five and three-fourths inches in length the canals of the lateral system are not completely covered, as in the sixteen-inch individual; they are slit lengthwise, as on Rhinochimaera, but on the larger one they are closed tubes with pores leading to the interior. The pectoral in this example does not reach backward of either the origin of the second dorsal or the base of the ventral. The arrangement of the spines on this small specimen is like that on the larger one; above the hind edge of the orbit on the outer side of the cranial canal there is a short longitudinal series of two or three; just inside of this at the inner side of the canal a series begins and extends forward for about twelve spines to the front end of the interorbital space, where it crosses to meet a similar series on the other side of the crown; close to the inner sides of the posterior extremities of these series there are several spines, sometimes but one; at each side of the median line, between the dorsals, there is a longitudinal series of fourteen or fifteen spines; a similar row of fourteen spines occurs at each side of the vertebral line between second dorsal and supracaudal.

Classification.

The intention in this section is to favor that nomenclature which was first applied with approximate correctness, and to follow the rules of priority in regard to designations for the higher groups as for the lower, the appeal for fair treatment in relation to credit and recognition being admitted to be quite as worthy in the case of the larger as in that of the smaller. It does not appear entirely just to carefully credit authorities for the names of species and at the same time to disregard the claims of those who have determined the values, affinities, and classification. Besides, a general acceptance of prior names tends to abate the multiplication of synonyms.

The history of the Chimaeroids begins at a much earlier date than that of Linné, as is seen in recognizable figures of Chimaera by Clusius, 1605, Exoticorum, page 137, by Aldrovandi, 1613, De Piscibus, Lib. III., pages 402 and 403, and by others; but it is no purpose of this writing to present either a complete history, bibliography, or synonymy. A few words on the origin of each of the terms adopted will suffice.

Linné used the name Chondropterygii in the first edition of his Systema, in 1735. He divided the fishes, as he knew them, into Plagiuri, Chondropterygii, Branchiostegi, Acanthopterygii, and Malacopterygii. The same arrangement appears in his edition of Artedi's work, 1738, and in subsequent editions of the Systema up to and including the seventh, 1748. His Chondropterygii were the genera Raia, Squalus, Acipenser, and Petromyzon.

Gronow, 1754, following Linné, recognized the horizontal-tailed fishes, the Plagiuri, and the perpendicular-tailed fishes; the latter he subdivided into those with bony-rayed fins, under the names Malacopterygii, Acanthopterygii, and Branchiostegi, and those with cartilaginous-rayed fins, the Chondropterygii, which latter included the genera Callorhynchus, Acipenser, Squalus, Raia, and Petromyzon. He had adopted most of his groups and genera from Artedi and Linné; among the additions the genus Callorhynchus is of most present interest. It is from Gronow's hand that that genus appears in the ninth edition of the Systema, 1756, without mention of Chimaera, though the latter was established by Linné in 1754, two years before the publication of that edition.

Linné dropped the name Chondropterygii in the tenth edition of the Systema, 1758, for Amphibia nantes, and there the group contains Petromyzon, Raia, Squalus, Chimaera, Lophius, and Acipenser. Callorhynchus of Gronow, 1754, was buried in Chimaera of Linné, 1754. The arrangement is similar in the twelfth edition, with addition for the worse of Balistes, Ostracion, Tetrodon, Diodon, Cyclopterus, Centriscus, Syngnathus, and Pegasus.

Gmelin, 1788, in his edition of the Systema, returned to the name Chondropterygii, and, dropping the name Amphibia nantes and taking out the genus Lophius, constitutes the group as in the tenth edition with these exceptions. The other fishes, practically the bony fishes, he placed in the groups Apodes, Jugulares, Thoracici, Abdominales, and Branchiostegi. The group Chondropterygii, with varying inclusiveness, has persisted.

Cuvier, 1798, in the Tableau Élémentaire, improved the arrangement by so much as concerns the removal of Acipenser from the Chondropterygii, and by retaining in the order Petromyzon, Raia, Squalus, and Chimaera His orders were *Les chondroptérygiens*, *Les branchiostèges*, *Les apodes*, *Les jugulaires*, *Les thorachiques*, and *Les abdominaux*. This distribution with Latin names was followed by Gravenhorst, 1807, who added to the Chondropterygii the genus Gastrobranchus of Bloch, 1795, for Myxine glutinosa of Linné, 1754.

La Cepède, 1798, divided the class into cartilaginous fishes and bony fishes. He accepted the Chondropterygii of his predecessors, but wrongly included various bony fishes, and though he carefully subdivided the groups he designated the minor divisions only by the names, apodes, jugulaires, thoracins, and abdominaux in each case, repeating these names over and over again.

Duméril, 1806, in the Zoologie Analytique, gave French names, derived from the Greek, to La Cepède's subdivisions. His first order of the cartilaginous fishes was the Trématopnés, with two families, the Cyclostomes and the Plagiostomes. His second order, and third family, he named Chismopnés; its contents were the so-called genera Baudroie, Lophie, Baliste, and Chimère. His third order, and fourth family, Eleuthéropomes, included Polyodon, Acipensère, and Pégase, and his fourth and last order of the cartilaginous fishes, the Télécbranches, contained three families properly belonging to the bony fishes. It is not necessary to follow the remainder of the orders, as they are outside of the limits of this paper. It will be seen that if the bony fishes improperly included are withdrawn from the second order, the Chismopnés, the only reason for its existence lies in the genus Chimaera. Duméril gives the derivation of the word Chismopnés as "de Χὶσμη fente et de Πνέος respirant." If he had derived it from Χάσμα or Χάσμη and made the word Chasmatopnés or Chasmopnés, or from Σχίσμα or Σχισμή, making the word to be Schismatopnés or Schismopnés there might have been less questioning of the etymology. It is only a change of a letter in either case, but authorities differ as to whether a correction should be applied.

Rafinesque, 1815, also lost sight of the limits between the cartilaginous and the bony fishes. He took Duméril's third order for his own sixth, and latinized the French name Chismopnés in the form Chismopnea. He placed in this order the family Branchismea, with three subfamilies, the Chimeria, the Balistia, and the Lophidia, and the family Meiopteria, with two subfamilies of eels, the Echelia and the Chlopsidia. All of this order except the Chimeria belonged among the bony fishes. His seventh order, the Tremapnea, was with considerable additions Duméril's first, the Trématopnés. Rafinesque put into this order (1) the Ophictia, consisting of three subfamilies of eels, (2) the Plagiostomia, Duméril's Plagiostomes, with two subfamilies, the Antacea, Sharks, and the Platosomia, Skates, and Rays, and (3) the Cyclostomia, with two subfamilies, the Lampredia and the Myxinia. As in case of Duméril's Chismopnés, the future of Rafinesque's Chismopnea depended wholly on his Chimeria.

Cuvier, 1817, again made a more exact separation of the Chondropterygii and the bony fishes, in which Rafinesque's Chismopnea were widely scattered; the Balistia became Plectognathes (Plectognatha Latr., 1825, Plectognathi Bonap., 1831), the Lophidia became Acanthoptérygiens, the Meiopteria became Malacoptérygiens apodes, and the Chimeria were placed in the Chondroptérygiens a branchies fixes under Les Chimères. The two genera Chimaera and Callorhynchus were accepted by Cuvier. His changes notwithstanding, the order Chismopnea still existed by virtue of the Chimaeroids contained in it.

Latreille, 1825, made use of the name Ichthyodera for his third class, Cuvier's Chondroptérygiens a branchies fixes, placing in this class two orders, the first, Selacii, Duméril's Plagiostomes, with three families, the Squalides, the Platysoma, and the Acanthorhina (Chimaerae), and the second, Cyclostoma, with two families, the Auloedibranchia (Petromyzonidae) and the Diporobranchia (Myxinidae). The name Acanthorhina cannot be looked upon as particularly appropriate since Blainville, 1816, had used Acanthorhinus for Spinacoid sharks.

Bonaparte, 1831, subdivided his subclass Chondropterygii into Section 1 Chismopnei (Branchiati) and Section 2, Trematopnei (Spiraculati). In the first he placed his order 6, Eleutheropomi (Sturiones), Family 32, Acipenseridae, and his order 7, Acanthorrhini, Family 33, Chimaeridae; and in the second he put his order 8, Plagiostomi (Selacii), Family 34, Squalidae, and Family 35, Rajidae, and his order 9, Cyclostomi, Family 36, Petromyzonidae. The same objections apply in the case of his order Acanthorrhini as in that of Latreille's, Family Acanthorhina.

Müller, 1834–35, settled the question of priority so far as concerned him by a name of his own, Holocephala. He included in this order only Thienemann's 1828, Family Chimaerae, Bonaparte's, 1831, Chimaeridae, containing the two genera discovered in 1754. The new name was supposed to be more appropriate for these Chondropterygii on account of the suspensorial connections of the lower jaws. However, if it be taken into consideration that the rostral cartilages of the Antacea, Sharks, and of the Platosomia, Skates and Rays, are outgrowths of the skull, and not articulated to it, while the same cartilages of the Chimaeroids are articulations, and not solid outgrowths from the skull, it will appear that the term Holocephala would be quite as appropriate for Plagiostomia as for Chismopnea.

The living Chimaeroids may be classified as below.

CHISMOPNEA Raf., 1815.

Chismopnés Dum., 1806.
Holocephala Müll., 1834.

Chondropterygii, with a compressed and massive body, an attenuated caudal region, a single external branchial cleft on each side, an erectile first dorsal spine and fin, a cartilaginous skeleton, a notochord not divided in vertebrae, a brain in which the hemispheres are remote from the optic lobes, a rostrum of which the cartilages are articulated to the skull, a dentition of two pairs of upper and one pair of lower dental plates, a frontal tenaculum, ventral tenacula and claspers on the male, and without distinct suspensorial cartilages for the lower jaws, without shagreen on the skin and without a diverticular gland on the intestine. Oviparous, the egg deposited in a horny case.

RHINOCHIMAERIDAE Garm., 1901.

Chismopnea, with an elongate, pointed, movable proboscis, with olfactory bulbs and hemispheres of the brain remote from one another, with a notochord surrounded by narrow cartilaginous rings, with a simple cartilage in each clasper of the male, and with subtubular lateral canals opening outward through a narrow slit. At present this family contains two genera of a single species each.

Species with compressed proboscis and having teeth with cutting edges and without tritors on the sides of the plates.

Rhinochimaera pacifica Mits.; Garm., 1901.

Species with depressed proboscis and with palatine and mandibular teeth bearing numerous tritors in several series on the sides of the plates.

Harriotta raleighana Goode & Bean, 1894.

CALLORHYNCHIDAE GARM., 1901.

Chismopnea, with a short proboscis ending in a retrorse leaf-shaped extremity, with palatine and mandibular teeth bearing one or two large tritors on the side of each plate, with a notochord not surrounded by narrow cartilaginous rings, with a simple cartilage in each clasper of the male, and with lateral canals that in the adult become tubular, opening outward through pores. Only one genus now known.

CALLORHYNCHUS GRONOW, 1754, 1763.

From the teeth of the specimens at hand five species are to be distinguished.

Callorhynchus callorhynchus Linné, 1758.
Callorhynchus milii Bory, 1823.
Callorhynchus smythii Benn., 1839.
Callorhynchus capensis Dum., 1865.
Callorhynchus tritoris Garm.

Callorhynchus antarcticus La C., *C. australis* Shaw, and *C. peronii* Dum. appear to be synonyms for *C. callorhynchus*. *Callorhynchus tasmanius* Rich. is not to be separated from *C. milii*. Dr. Filippi, 1892, described two species without giving the dental characters; one of these, his *C. antarticus*, resembles *C. smythii*, the other is much like *C. callorhynchus*. Dr. Alcock, 1891, secured indications of the existence of another species from the Bay of Bengal; it was named *C. indicus* by Garman, 1899, from the horny egg case, and is probably to be found only at great depths. The fossil species *C. hectori* Newton, 1876, is to be placed with *C. capensis*, at least until more than the dentition is known about it.

CHIMAERIDAE THIEN., 1828.

Chimaerae THIEN., 1828.
Chimaeridae BONAP., 1831.

Chismopnea without a proboscis, with tritors situated anteriorly on the edges of all the dental plates, with hemispheres and olfactory bulbs of the brain in contact, with a notochord surrounded by narrow cartilaginous rings, with a trifid cartilage in each clasper of the male, and with sulcate lateral canals.

CHIMAERA Linné, 1754, 1758.

Six living species of this genus are recognized.

Chimaera monstrosa Linné, 1754, 1758.
Chimaera phantasma Jordan & Snyder, 1900.
Chimaera affinis Capello, 1868.
Chimaera colliei Lay & Bennett, 1839.
Chimaera ogilbyi Waite, 1898.
Chimaera mitsukurii (Dean) Jordan & Snyder, 1904.

The synonymy of *Chimaera monstrosa* includes *C. argentea* Ascan., 1772, *C. borealis* Shaw, 1804, *C. mediterranea* Risso, 1826, *C. cristata* Faber, 1829, and *Callorhynchus centrina* and *Call. atlantica* of Gronow and Gray, 1854; and that of *Chimaera affinis* contains *C. plumbea* Gill, 1877, and *C. abbreviata* Gill, 1883.

Chimaera monstrosa and *C. phantasma* have the anal fin distinct from the subcaudal; they differ in this respect from the other species. One of the latter, *C. colliei*, has been made the type of a new genus, *Hydrolagus*, by Gill, 1862. This genus was originally "distinguished from Chimaera by the absence of an anal fin and the triple division of the sexual organ of the male." The absence of the triple division of the clasper is more apparent than real, since the cartilage of that organ is trifid in males of all the species of the genus. On *Chimaera colliei* two of the divisions of the cartilage are wrapped together by the skin so as to present the appearance of a single division. If absence of the anal fin is to make generic separation necessary, then *Chimaera affinis* would be placed with *C. colliei*, though actually farther removed by structure from the latter than *C. monstrosa*. As may be seen by comparison of the figures published here, in dental characters and in those of the brain and the skeleton *Chimaera colliei* agrees closely with *C. monstrosa*. In some respects *Chimaera mitsukurii* accords with *C. colliei*, as in the apparently bifid claspers and the lack of an anal fin, but it has a much longer caudal filament than that species.

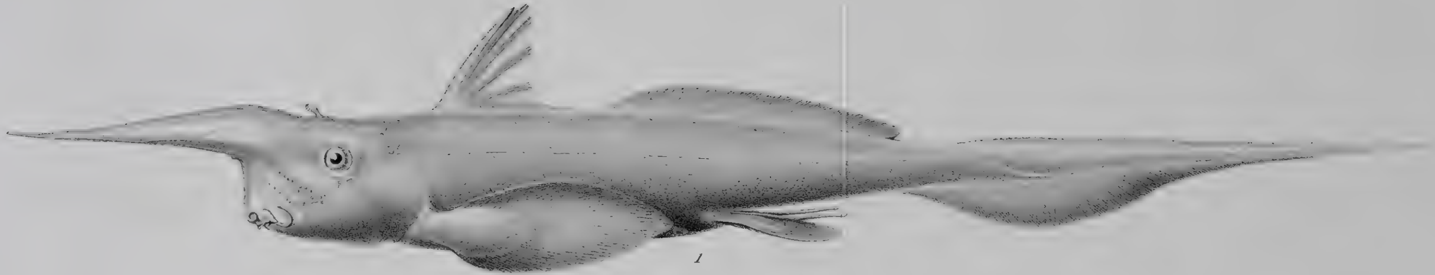
The right of Chimaera to be considered the most differentiated of the Chismopnea will hardly be questioned. By rostrum, dentition, brain, claspers, and lateral system it is the farthest removed from Rhinochimaera.

PLATE 1.

Rhinochimaera pacifica Mits.; Garm.

Fig. 1. Side view, $\frac{1}{3}$ natural length.

Fig. 2. Side view of trunk, showing intestines and skeletal features, $\frac{2}{3}$ nat.



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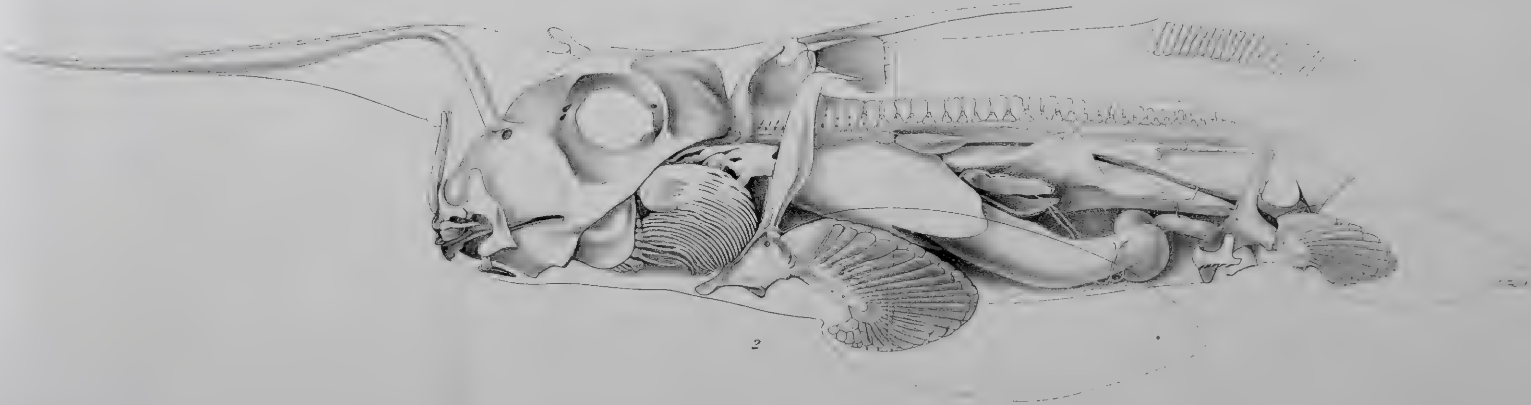

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PLATE 2.

Fig. 1. Head of Rhinochimaera pacifica, seen from above, $\frac{1}{2}$ natural length.
Fig. 2. Head of Rhinochimaera pacifica, seen from below, $\frac{1}{2}$ nat.
Fig. 3. Head of Harriotta raleighana G. & B., seen from above, $\frac{5}{6}$ nat.
Fig. 4. Head of Harriotta raleighana, seen from the side, $\frac{5}{6}$ nat.
Fig. 5. Head of Harriotta raleighana, seen from below, $\frac{5}{6}$ nat.

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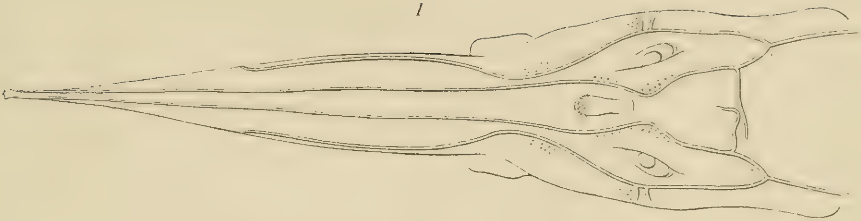

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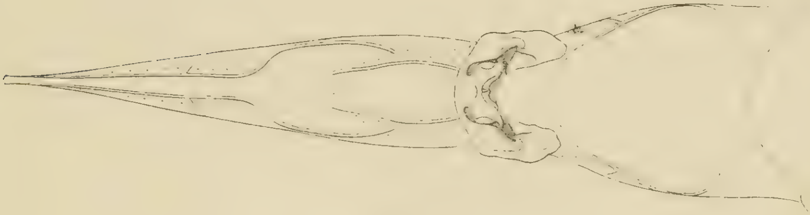

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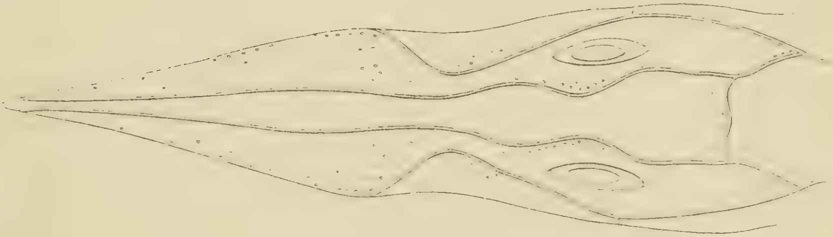

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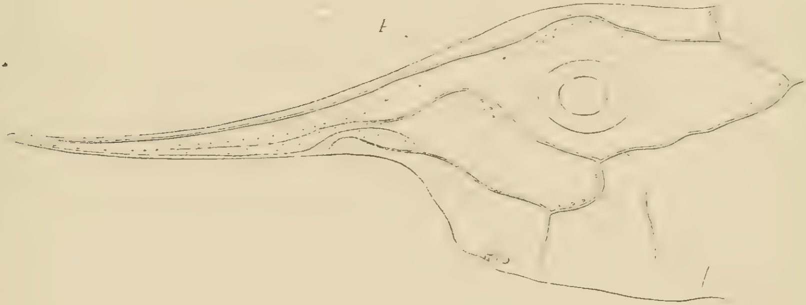

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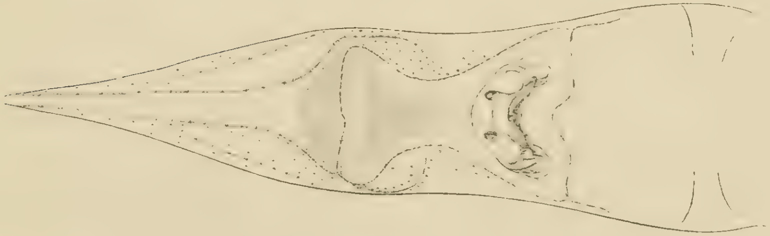

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PLATE 3.

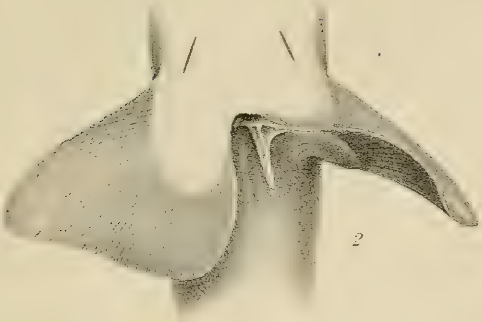
Fig. 1. Rhinochimaera pacifica, ventrals, claspers, and ventral tenacula, $\frac{1}{2}$ natural length.

Fig. 2. Callorhynchus callorhynchus Linné, ventrals, claspers, and ventral tenacula of young, nat. size.

Fig. 3. Carcharhinus terrae-novae Rich., ventrals and claspers, nat. size.

Fig. 4. Rhinochimaera pacifica, diagram of claspers and ventral tenacula, nat. size.

Fig. 5 Rhinochimaera pacifica, ventral fin and clasper, as seen from above, $\frac{2}{3}$ natural length.



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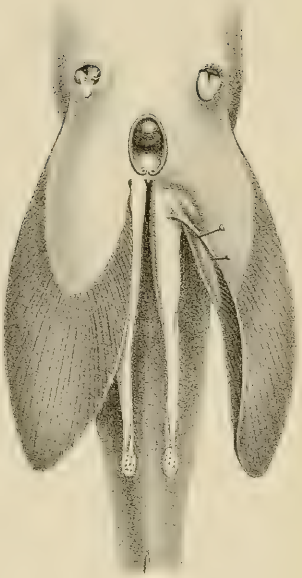

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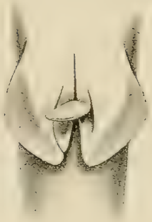

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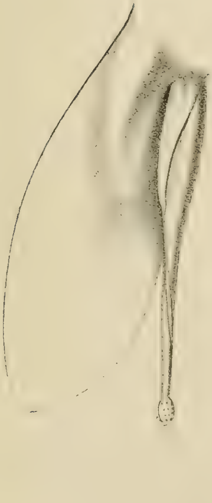

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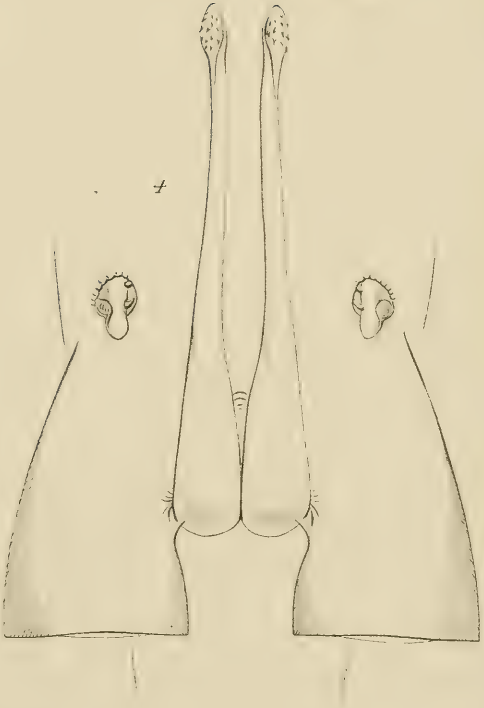

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PLATE 4.

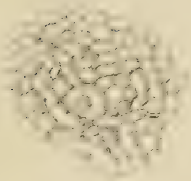
Fig. 1. Harriotta raleighana, appearance of skin on the flank, 4 times natural length.

Fig. 2. Rhinochimaera pacifica, armature of upper edge of supracaudal fin, 3 times nat.

Fig. 3. Rhinochimaera pacifica, lateral canal and rings, 8 times nat.

Fig. 4. Rhinochimaera pacifica, intestine slit open to show spiral and valves.

Fig. 5. Raia laevis Mitch., ventral fins with claspers turned forward.



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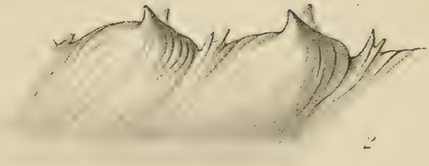

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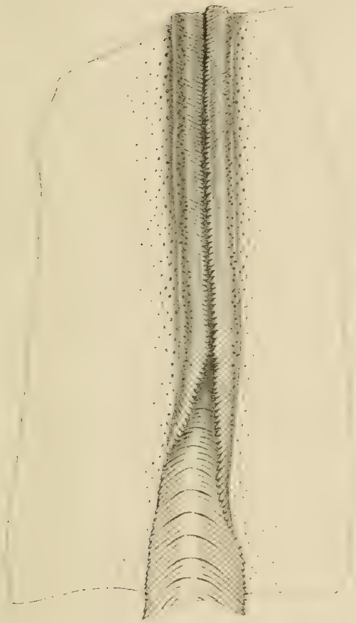

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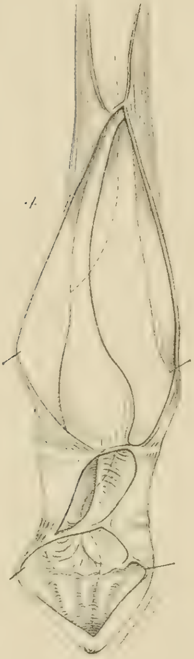

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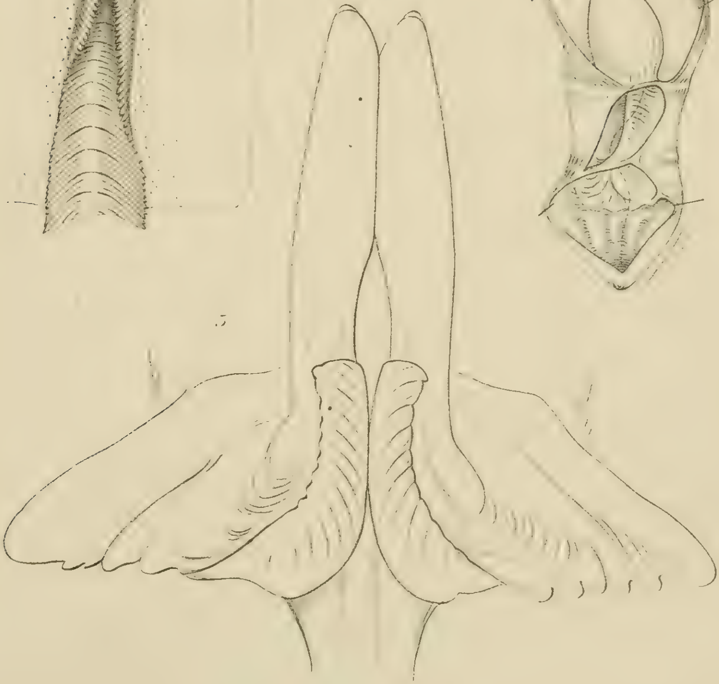

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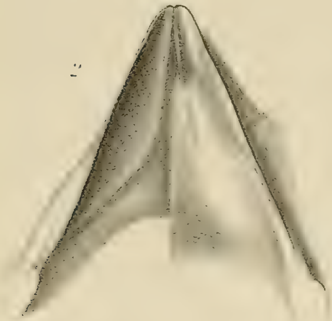
PLATE 5.

Fig. 1. Rhinochimaera pacifica, vomerine and palatine teeth from below, nat. size.
Fig. 2. Rhinochimaera pacifica, mandibular teeth, seen from above, nat. size.
Fig. 3. Harriotta raleighana, vomerine and palatine teeth, seen from below, twice nat. length.
Fig. 4. Harriotta raleighana, mandibular teeth, seen from above, twice nat.
Fig. 5. Harriotta raleighana, tongue showing upper surface, twice nat.
Fig. 6. Harriotta raleighana, vomerine and palatine teeth of young, twice nat.
Fig. 7. Harriotta raleighana, mandibular teeth of young, twice nat.
Fig. 8. Harriotta raleighana, vomerine and palatine teeth of very young, 4 times nat.
Fig. 9. Harriotta raleighana, mandibular teeth of very young, 4 times nat.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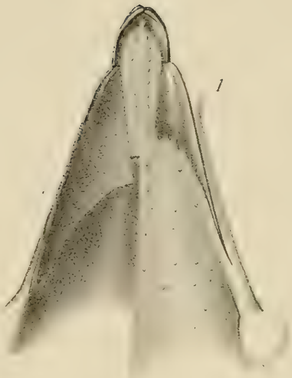
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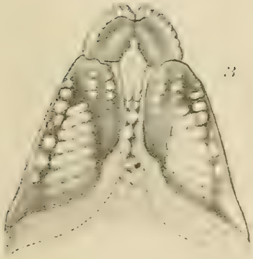
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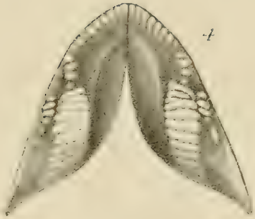
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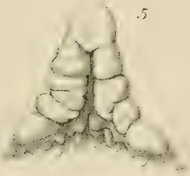
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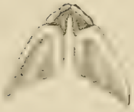
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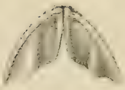
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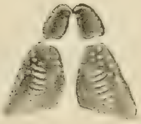
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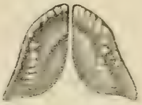
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B. Meisel, lith. Boston

PLATE 6.

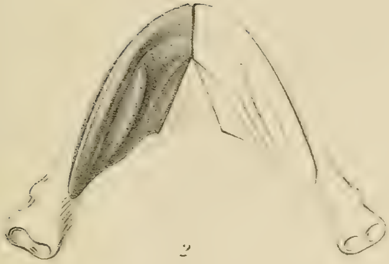
Figs. 1 and 2. Callorhynchus smythii Benn., vomerine and palatine and mandibular teeth, nat. size.

Figs. 3 and 4. Callorhynchus smythii, vomerine, palatine, and mandibular teeth of very young, nat. size.

Figs. 5 and 6. Callorhynchus capensis Dum., vomerine, palatine, and mandibular teeth, nat. size.

Figs. 7 and 8. Callorhynchus milii Bory, vomerine, palatine, and mandibular teeth, nat. size.

Fig. 9. Callorhynchus tritoris Garm., vomerine teeth and one palatine tooth, nat. size.



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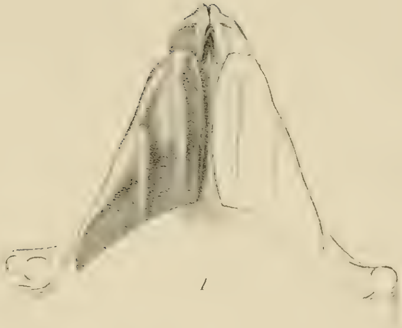

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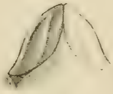

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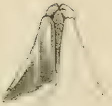

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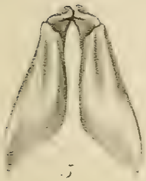

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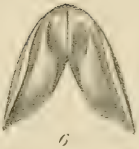

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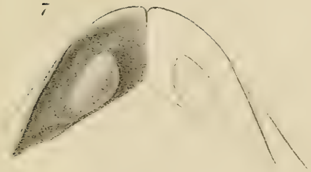

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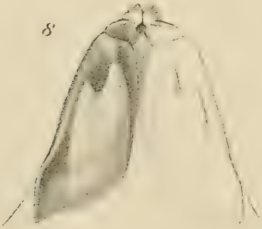

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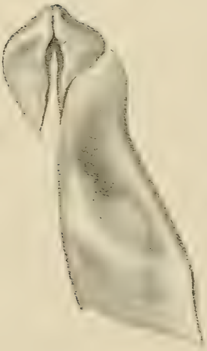

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J. Henry Blake, del.

PLATE 7.

Figs. 1 and 2. Chimaera monstrosa Linné, vomerine, palatine, and mandibular teeth, nat. size.

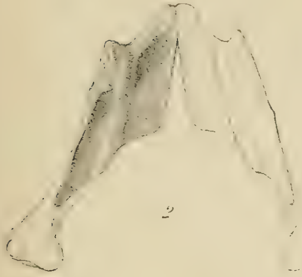
Fig. 3. Chimaera monstrosa, much-worn mandibular tooth from the inner side, nat. size.

Figs. 4 and 5. Chimaera colliei Benn., vomerine, palatine, and mandibular teeth, nat. size.

Fig. 6. Chimaera colliei, outlines of inner side of mandibular tooth, nat. size.

Figs. 7 and 8. Callorhynchus callorhynchus Linné, vomerine, palatine, and mandibular teeth, nat. size.

Fig. 9. Callorhynchus callorhynchus, mandibular tooth, from inner side, nat. size



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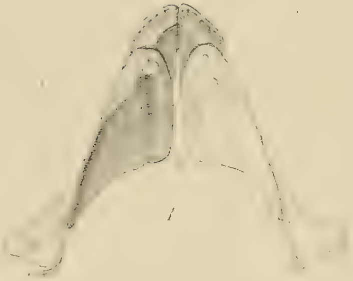

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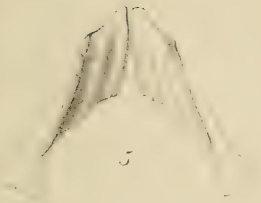

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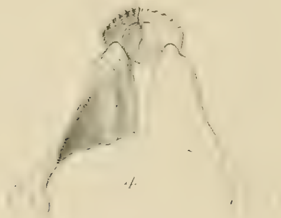

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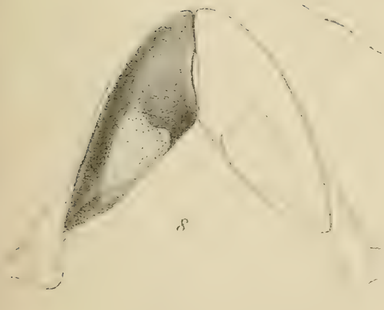

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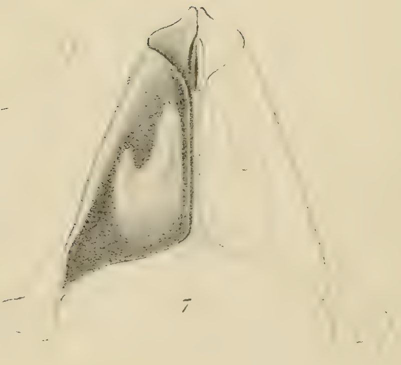

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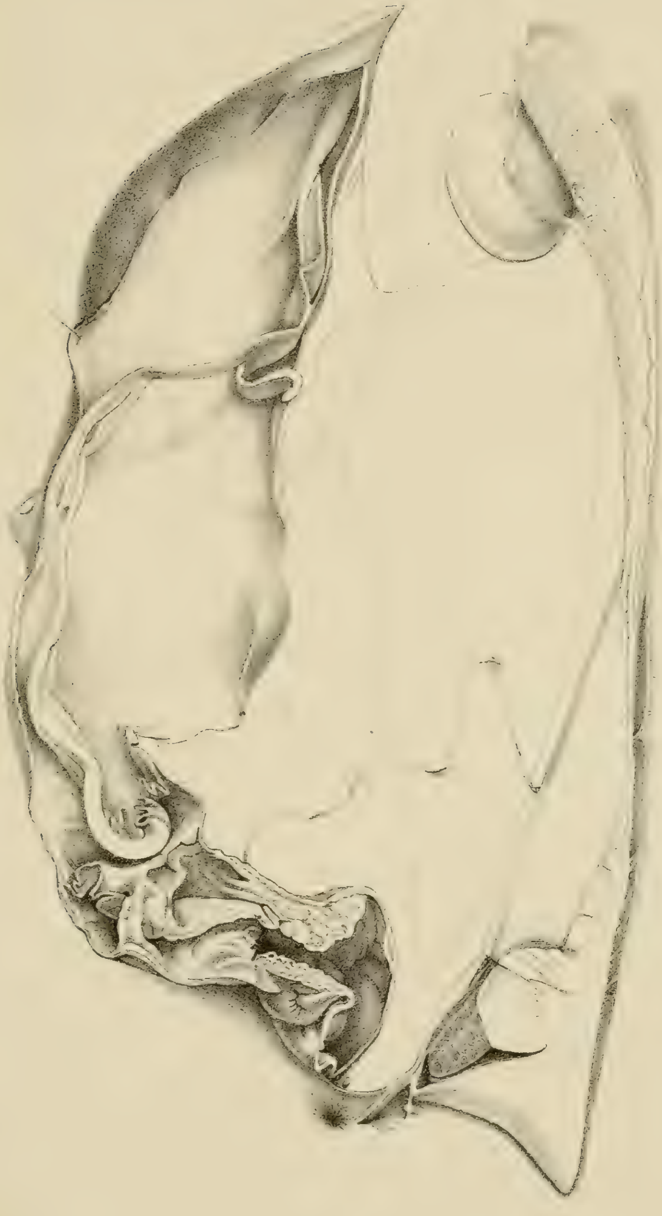
B Meisel lith Boston

PLATE 8.

Rhinochimaera pacifica.

Intestine, slit open to show valves and spiral, spermaries, and kidneys, with liver and pancreas in outline.



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B.Meisel, lith Boston

PLATE 9.

Rhinochimaera pacifica.

Fig. 1. Liver, gall-bladder, and ends of stomach and intestine, with heart in outline, nat. size.

Fig. 2. Lower view of genital and urinary organs, with intestine outlined, nat. size.

Fig. 3. Heart, nat. size.

Fig. 4. Bulbus slit open to show the rows of valves, 4 times natural length.

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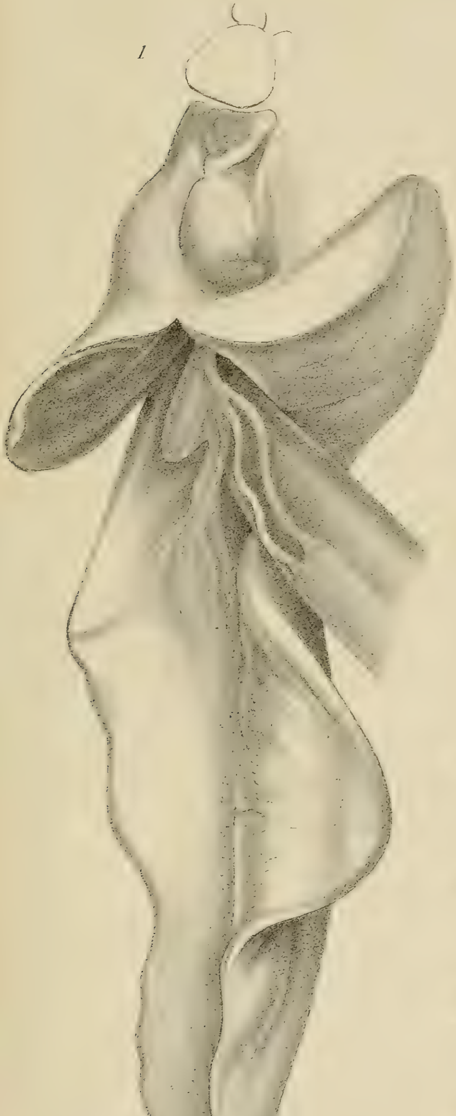

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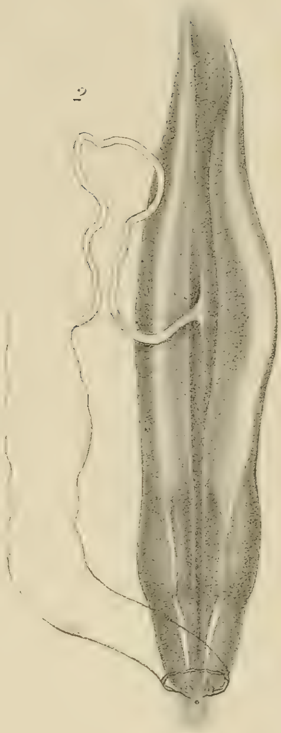

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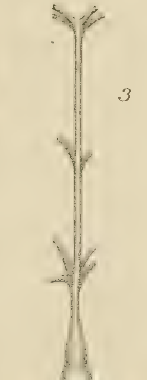

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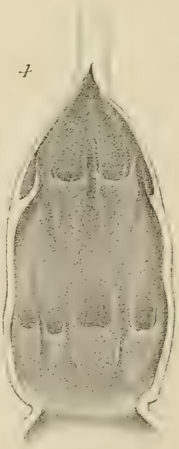

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PLATE 10.

Callorhynchus callorhynchus.

Skeletal features and viscera of very young specimen, from the side, twice nat.

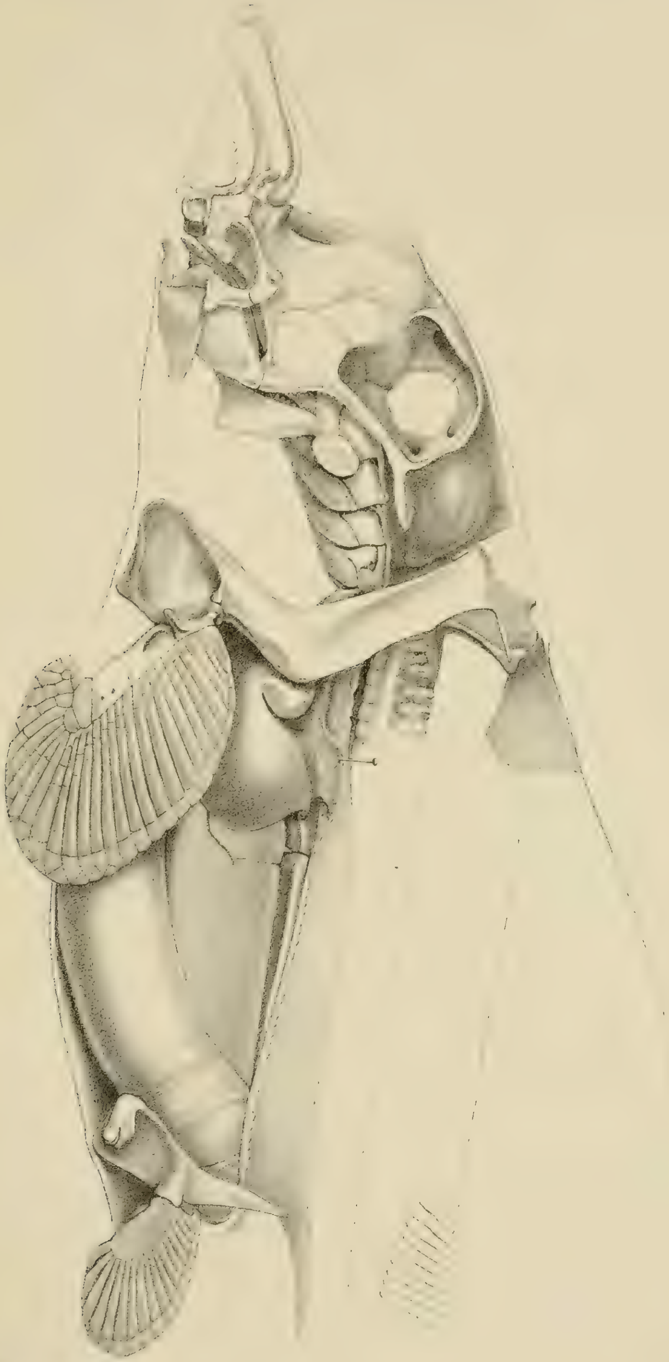

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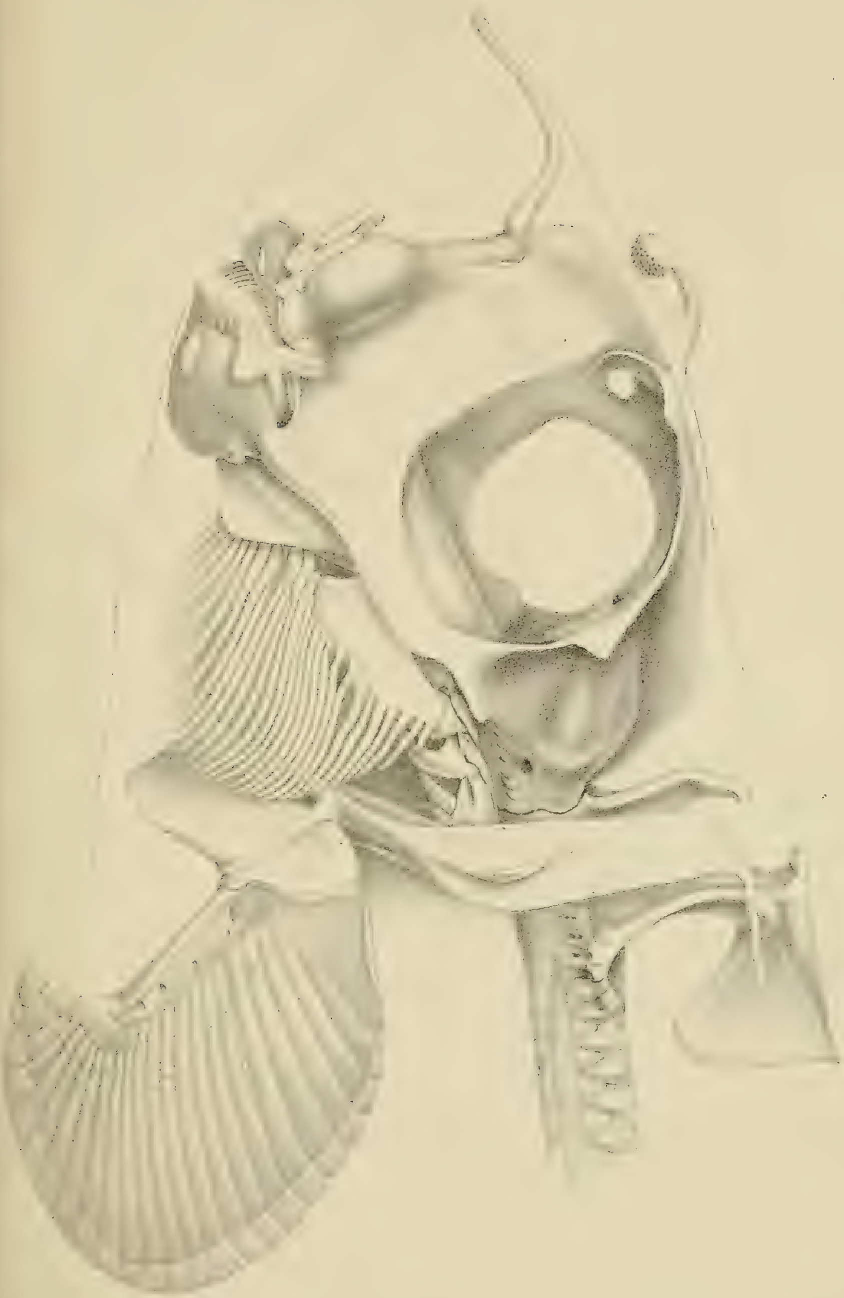
PLATE **11**.

Chimaera monstrosa.

Skeletal features of head and anterior part of body, from the side, nat. size.



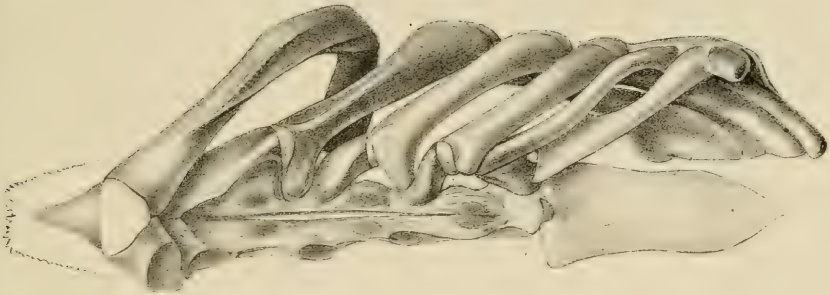
J. Henry Blake, del.

B. Meisel lith. Boston

PLATE 12.

Rhinochimaera pacifica.

Fig. 1. Branchial cartilages of left side from below, nat. size.
Fig. 2. Branchial cartilages of left side from above, nat. size.
Fig. 3. Glossohyal, ceratohyal, epihyal, and anterior basibranchial from the side, nat. size.



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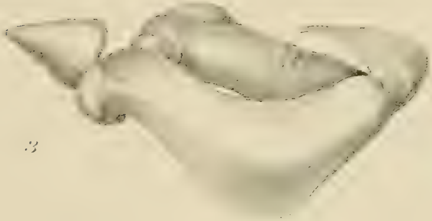

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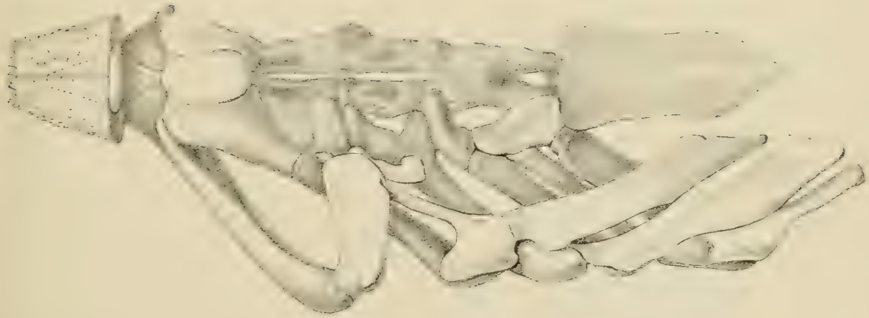

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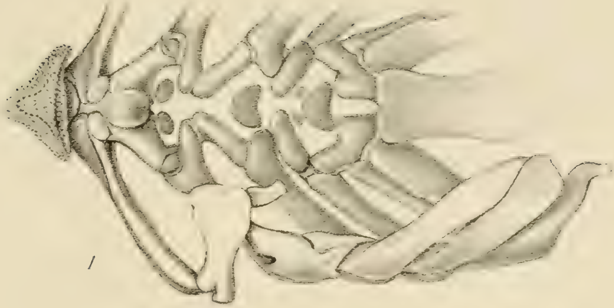
PLATE 13.

Fig. 1. Chimaera monstrosa, branchial skeleton, seen from above, nat. size.
Fig. 2. Chimaera colliei, branchial skeleton, upper view, nat. size.
Fig. 3. Callorhynchus smythii, branchial cartilages, upper view, nat. size.



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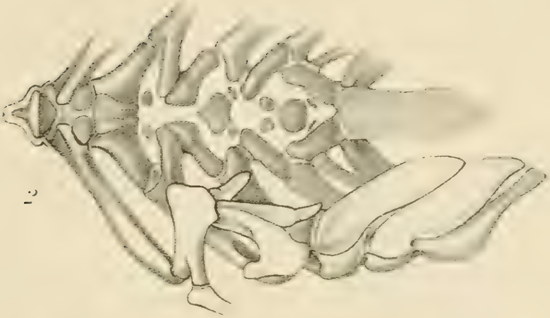

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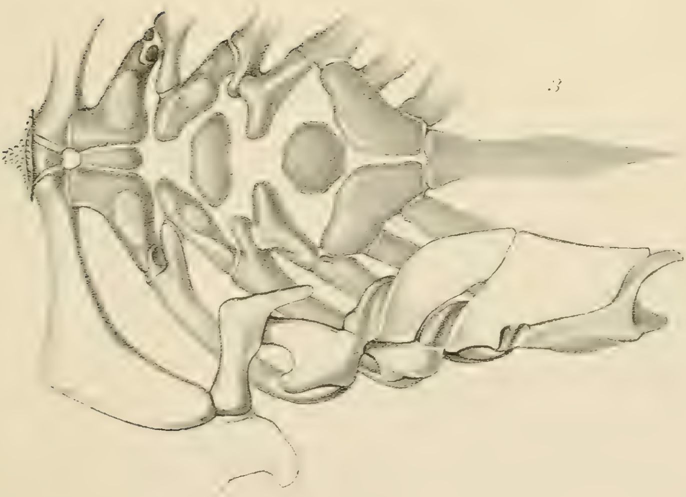

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J Henry Blake del

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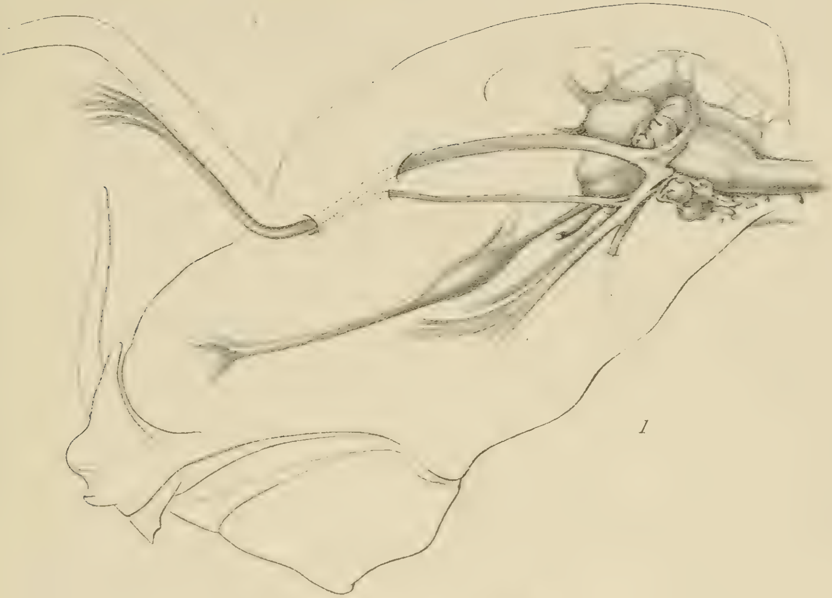
PLATE **14**.

Rhinochimaera pacifica.

Figs. 1 to 3. Brain, from the side, from below, and from above, nat. size.
Figs. 4 to 7. Otoliths, 4 times natural length.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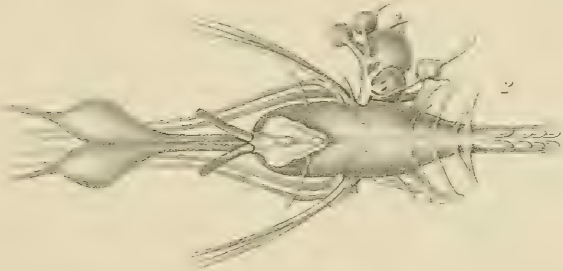
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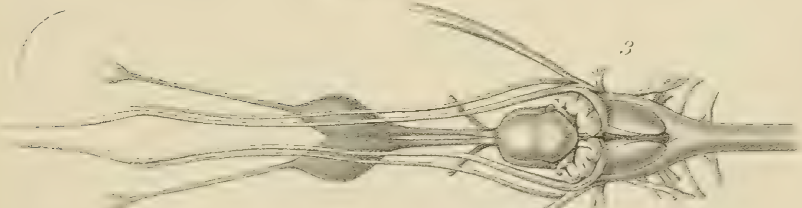
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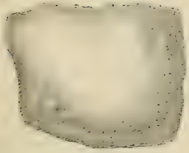

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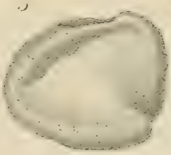

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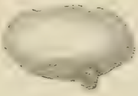

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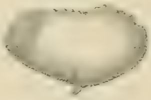
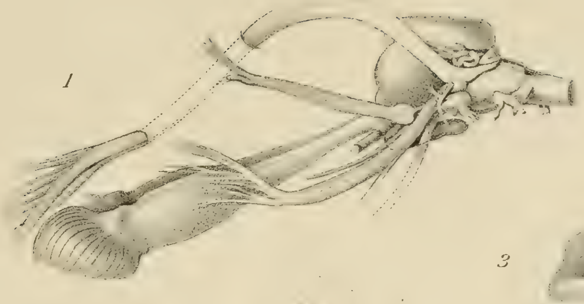


J. Henry Blake, del. B. Meisel, lith. Boston

PLATE 15.

Figs. 1 and 2. Chimaera colliei, brain from the side and from above, nat. size.
Fig. 3. Chimaera colliei, otolith, 4 times nat. length.
Figs. 4 and 5. Callorhynchus milii, from the side and from above, nat. size.



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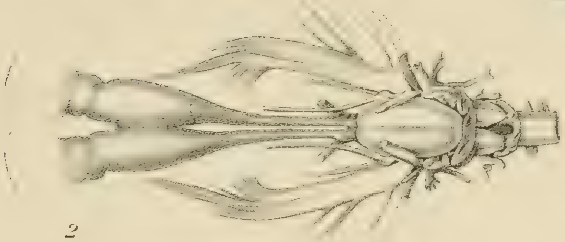

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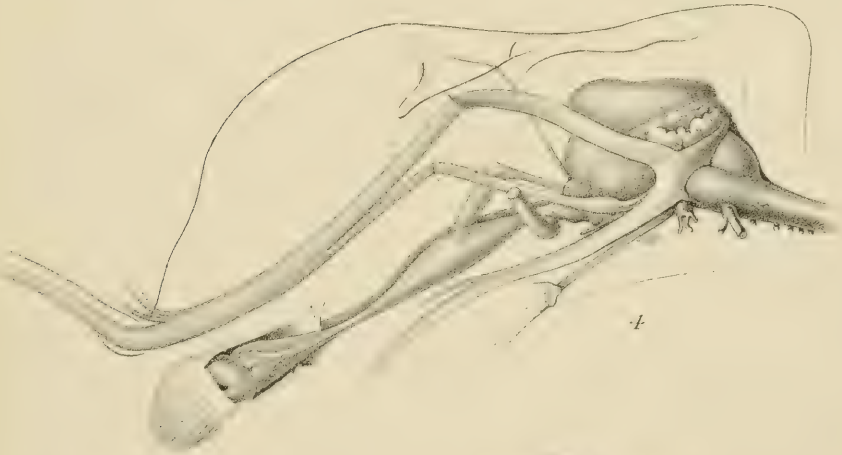

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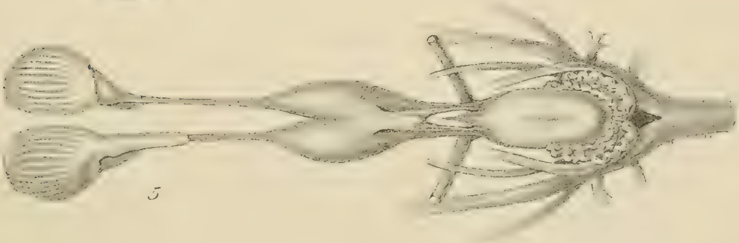

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BULLETIN

OF THE

MUSEUM OF COMPARATIVE ZOÖLOGY

AT

HARVARD COLLEGE, IN CAMBRIDGE.

VOL. XLII.

(Geological Series, VI.)

CAMBRIDGE, MASS., U. S. A.
1903–1905.

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Introduction.

In the summer of 1902, the writer made his third visit to the region of the Colorado canyon. The results of the first visit in 1900 have already been published (a, b);[1] the results of the second visit in 1901 were of relatively small import and are here presented along with those of the third. The last excursion was undertaken partly as a means of providing opportunity in field work for some of our advanced students in geology at Harvard, two of whom, Messrs. Ellsworth Huntington and J. Walter

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[1] Dates, letters, or page numbers in parenthesis refer to the bibliography at the close of the article.

Goldthwait, were enabled by the generous contributions from several friends of the geological department to spend five weeks in the plateaus north of the canyon. An abstract of their report has been published in the Journal of Geology and a fuller statement of their results will form a later member of this Bulletin.

Our itinerary, shown by a broken line with numbers for dates on Figure 1, was as follows: — From Provo by rail to Marysvale, July 12; Marysvale by wagon to Kanab, July 13 to 17; Kanab, in saddle with wagon outfit, to Mt. Trumbull and the Colorado canyon at Toroweap, July 18 to 21; on the esplanade of the canyon, July 22; from the canyon to Toquerville, July 23 to 29; about Toquerville with wagon, July 30 to August 5. On the latter date I left my companions at St. George to continue their study of the Toquerville district, and went by wagon and rail to Salt Lake City, and thence to Nevada and Oregon, as will be described in a later number of this Bulletin.

The observations made in 1900 led to certain departures from conclusions previously published, especially as to the time of the production of the great north-south faults by which the plateau province is traversed. It was believed that the greater part of the faulting had been accomplished before the uplift of the region by which the erosion of the Colorado canyon was initiated; that is, during the plateau cycle of erosion, so-called because the removal of a great thickness of rocks from the broad area of the plateaus north and south of the canyon was then effected (a, p. 119). It was further thought that during the canyon cycle of erosion extensive areas of weak Permian rocks were stripped from the uplifted region while the Colorado river was corroding its canyon (p. 139); and it was suspected that the western boundary of the uplifted region lay along the line of the Grand wash fault, on which a relatively late movement, long after an earlier movement, served to place the plateau region on the east above the Basin region on the west (p. 148).

The first of these conclusions will here be further substantiated; but at the same time it will be shown that modern faulting of large amount has taken place on the Hurricane fault fifty miles and more north of the canyon. Additional evidence will be presented as to the stripping of weak Permian strata from the plateaus north of the canyon during the canyon cycle. Perhaps the most important result of the summer's work bears on the recent movement along the Grand wash fault, which is now promoted from the rank of a supposition to that of a reasonable certainty, as will appear from the work of my student companions. Several collateral problems are discussed, as appears in the table of contents.

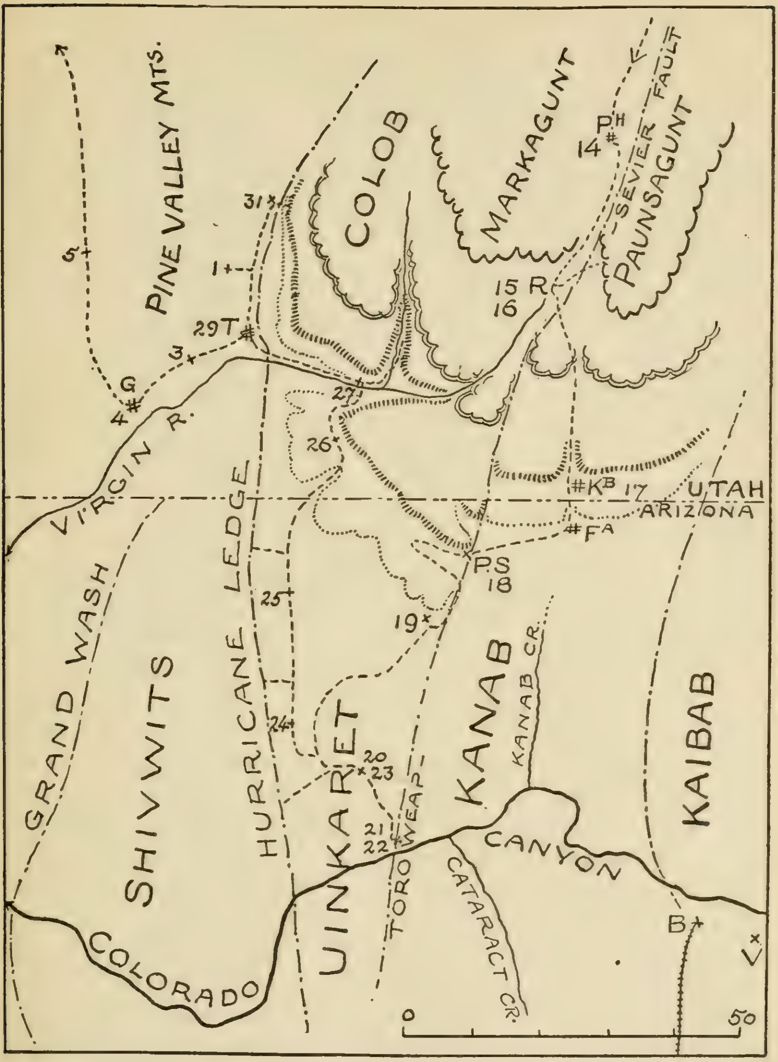
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FIGURE 1.

Route map. The numbers alongside of the broken line showing the route followed indicate the dates in July (14–31) and August (1 to 5), 1902, when certain points were passed. The abbreviations are as follows: — A, Grand View Hotel; B, Bright Angel Hotel. These two points, south of the canyon, were visited in the summer of 1901. FA, Fredonia; G, St. George; KB, Kanab; PH, Panguitch; P. S., Pipe spring; R, Ranch; T, Toquerville.

The Sevier-Toroweap Fault.

Previous Statements. — The western part of the Plateau province is traversed by a series of monoclinal flexures and faults whose general course is from north to south as shown on sheet III of Dutton's Grand Canyon Atlas. Parts of two important faults are now to be described: the first is presented in this chapter under the double name given above; the second is the Hurricane fault, to which the next chapter is devoted. In Dutton's reports, the Sevier fault is traced southward from San Pete valley about two hundred and twenty miles to an ending near Pipe spring. Then after an unfaulted interval of twenty-five miles, the Toroweap fault is begun at a point about twenty miles north of the canyon, and continued closely in line with the prolongation of the Sevier fault to a doubtful termination twenty-five miles south of the canyon. These faults and their fellows are associated by Dutton with the Pliocene uplift of the region (see references in my previous article, b, p. 114), indeed, with so recent an epoch in the history of the plateaus that "every fault in the district is accompanied with a corresponding break in the topography." No instance is recalled by Dutton where "the lifted beds are planed off by erosion, so as to make a continuous level with the thrown beds" (b, p. 130). It has seemed to me, however, that this generalization is incorrect; that the faults are much older than the general (Pliocene) uplift of the region; that in several instances the existing escarpments are not the immediate product of faulting, but are the result of erosion on a faulted mass which may have been essentially baselevelled in the cycle of erosion initiated by the faulting, and which now shows escarpments along the fault lines because of differential denudation in a later cycle; and that the absence of an escarpment between the supposed ends of the Sevier and the Toroweap faults is therefore not sufficient evidence of the independence of these two great displacements.

It is certainly true, as will appear in the sequel, that relatively recent movement has taken place on some of the faults, so that the more resistant rocks still stand up in bluffs worn but little back from the fault line; an example of this kind will be described where the Toroweap fault crosses the canyon, and a much more imposing example is found in the northern part of the Hurricane fault. But there are often no signs of recent movement, and a large amount of erosion even in the stronger rock masses has usually been effected since their displacement occurred. The various lines of evidence that indicate a considerable antiquity for the faults, and the possible continuity of faults across intervals where no break occurs in the topography have therefore an important bearing on the physical history of the region. The following account of certain significant localities on the line of the Sevier-Toroweap fault proceeds from north to south.

THE FAULT AT UPPER KANAB. — The district that includes the headwaters of the Sevier, the Virgin, and the Kanab, on the Kanab (Utah) Sheet, U. S. Geological Survey topographical maps, is of monoclinal structure with gentle eastward dip, in which the Sevier fault, Figure 2, uplifts the eastern half with a heave of nearly one thousand feet (Dutton, a, p. 31). The youngest of the dislocated strata are the Paunsagunt Tertiaries, which are classed as Eocene. Whether the fault occurred early or late in post-Eocene time can be best determined by inquiring into the changes effected by general erosion in the topography consequent upon faulting.

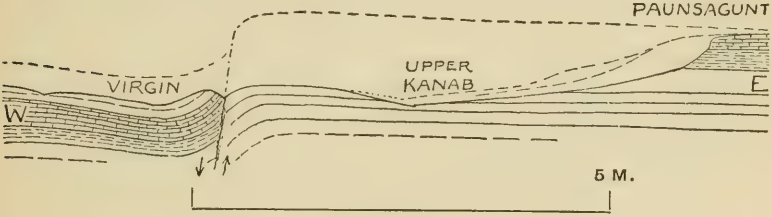

FIGURE 2.

General cross-section at Upper Kanab.

The most manifest effects of this fault upon local drainage would have been to produce longitudinal consequent streams in the trough parallel to and somewhat west of the fault line, and short consequent streams flowing west and eastward from the divide, as indicated by the dotted profile of Figure 2. The upper waters of the Sevier and of the Virgin may be in some way related to the inferred longitudinal consequent streams west of the fault, but the consequent divide east of the fault is now replaced by the subsequent valley of the Upper Kanab creek, eroded on the weak Cretaceous strata east of the fault and close along the line that should have initially stood at the greatest height. The simplest explanation for such a valley involves two cycles of erosion, separated by a regional uplift without significant renewal of faulting. During the first cycle it may be supposed that the cliff-making Paunsagunt strata were worn a few miles back (eastward) from the fault escarpment, and that the weaker Cretaceous strata were thus exposed in a belt between the fault line and the retreating Paunsagunt cliffs; the drainage of the Cretaceous belt at this time being very probably effected by headward obsequent prolongations of the originally short west-flowing consequents, whereby the east-flowing consequents on the Paunsagunt had been progressively beheaded. In the second cycle, it is reasonable to infer that Kanab creek gained possession of the weak Cretaceous belt by headward erosion from the south, and that the east-flowing consequents on the Paunsagunt were thus still further undercut and beheaded.

There is some independent evidence of the correctness of these suppositions. Where the road from Panguitch to Kanab crosses the divide between the Virgin and Upper Kanab creek a little south of Ranch, there is a sheet of basalt that seems to spread horizontally across the fault line, covering Tertiary and Cretaceous strata indifferently, as in Figure 3. It is thus suggested that at the time of the basalt eruption the effects of faulting had been locally obliterated, and this gives warrant for the first cycle of erosion. To-day the basalt forms an upland affording a fine view in nearly all directions, and the valleys are eroded several hundred feet beneath it; and this gives warrant for the second cycle of erosion. Moreover, the headwaters of Kanab creek are to-day extending their drainage area towards the north and east, and this suggests that they have been doing so in the past; in other words, Kanab is a growing subsequent stream, successfully invading the drainage area of its neighbors.

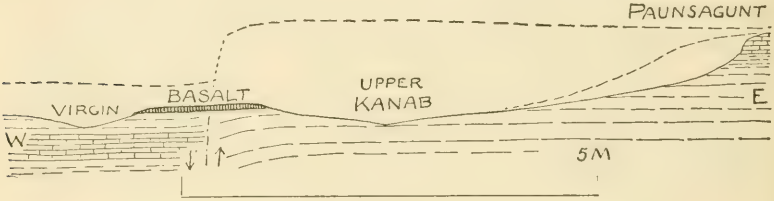

FIGURE 3.

General cross-section three miles south of Upper Kanab.

In view of so great a transformation from the topography supposedly initiated by the faulting to the existing topography produced by erosion, it seems necessary to give the Sevier fault a date somewhat earlier than late Tertiary time: yet it should not be thrown too far back toward the

Eocene, for the Eocene strata west of the fault seem to have been deformed by an east-dipping monoclinal flexure as in Figure 2, before they were faulted; and a significant period of post-Eocene time must be allotted not only to the production of the flexure, but also to the rearrangement of the deep-seated telluric forces, so that a fault with uplift on the east should succeed a flexure with uplift in the west.

The existing condition of the Sevier fault is well shown between Seaman's Ranch on the Virgin and the group of ranches known as the Upper Kanab on the creek of that name. The road forks between these two settlements and crosses the fault at points about a mile apart. The upper white and red members of the Tertiary series here exposed west of the fault are submaturely dissected, so that the eastern border of the Markagunt plateau in this district shows open valleys branching among rounded hills, whose slopes often exhibit contouring ledges. Three small shallow "lakes" or marshy meadows held back by fans from lateral ravines lie in the valley of the Virgin just west of the fault. The gentle eastward dip of the strata increases to about 10° near the lakes; but where the southern road crosses a white-soil ridge a little further eastward, the dip is 10° or more to the west. East of the ridge there is a rapid descent into the open valley of the Kanab (altitude, 6700′), eroded in the Cretaceous sandstones and shales and somewhat lower than the neighboring valley of the Virgin. The fault must pass close to the notch where the road crosses the ridge.

A mile north of another notch in which the northern road crosses the ridge of west-dipping Tertiaries, the Cretaceous strata rise in a hill adjoining the Tertiaries on the east, and here a ravine close along the fault line almost discloses the actual surface of faulting. The yellow-brown sandstones and gray shales of the Cretaceous dip 20° NW., while the white Tertiary limestones and shales dip about 10° W., but their bedding is not clearly shown. These dips, it will be observed, are locally reversed from the eastward slope of the presumably earlier monoclinal flexure and evidently result from the drag of the fault. The course of the fault line, measured by the trend of the ridge that follows it so closely, is here S. 25° W., true bearing. The valley of Kanab creek is broadly opened, and the general front of the Pink cliffs rises to the Paunsagunt plateau, attaining an altitude of nine thousand feet, about eight miles east of the fault line. The profile of the plateau is indented by the high-level valleys of east-flowing streams, whose heads are constantly undercut by the encroaching branches of the Kanab.

In view of these various facts, it seems inadmissible to regard the

Sevier fault as immediately responsible for the existing topography; the date of the fault must be sufficiently remote to allow much consequent and subsequent erosion after it occurred.

Our route southward from Upper Kanab led us obliquely to the east of the Sevier fault line, which was not seen again until we turned west from Fredonia toward Pipe spring. The two following sections are devoted to the notes made on the way there.

THE JURASSIC SANDSTONES. — The cross-bedding of the Jurassic sandstones exposed in the canyon of Kanab creek through the platform that fronts in the White cliffs, with an altitude of 6700 feet and a relief of a full thousand feet, was one of the most extraordinary structures seen during the summer. It has already been well described by Dutton (a, p. 150; b, p. 35), but no one can pass its superb escarpment without wishing to tell something of its wonders. Characteristic views of its form and stratification are given in Plates 1 A, 1 B, 2 A. The sandstone is white, clean, and even-textured, with its oblique layers slanting at angles of from 20° to 26°, and descending to great sweeping curves that turn gently tangent to the floor on which they rest. Southward dips are more common than northward. We looked in vain for the completed summit curves of the oblique beds: none were to be seen. Each group of oblique layers is truncated by the removal of its upper part, and the lower part that remains is too incomplete to indicate with certainty the origin of this very remarkable formation. Whatever was the entire original form of the successive deposits which the oblique layers possessed immediately at the time of their accumulation, the upper part of each group seems in all cases to have been more or less deeply worn away before the next higher group of layers was deposited. The surfaces of truncation are of gentle declivity and curvature, and often seem nearly or quite horizontal. Some of the groups of oblique layers are still twenty, thirty, or more feet in thickness, the successive layers descending with remarkable regularity and parallelism from top to bottom. Other groups are reduced to hardly more than a few feet in thickness, although their horizontal extent often exceeds a hundred feet, thus suggesting that their present vertical measure is but a small fraction of their original height. We saw no rippling; all the layers show very smooth lines on the outcrop face. The surfaces of truncation or local unconformity are marked by no uncertain deposits. The underlying layers are sharply cut off; the overlying layers rise gradually at first and then more steeply in long, sweeping curves. The sandstones seem to retain their cross-bedding up to the top of the cliffs, but in the upland north of the escarpment they are overlaid by evenly bedded horizontal calcareous strata.

Wind action in an ancient desert seems more competent than any other agent to produce the observed structures, but we could not discover any critical and decisive proof of this suggestion. It would be difficult to select a more attractive problem in structural geology than would be offered to a student who should trace this extraordinary formation around its outcrops in the White cliffs until some demonstrable conclusion as to its origin should be reached. The dissection of the Jurassic platform back from the cliffs by obsequent, south-flowing streams gives abundant opportunity for viewing the curious structure of the sandstones. The little valley that our road followed southward gathers the drainage from a small area of open surface on the lower Cretaceous strata, gradually sinks below the Jurassic platform, and eventually joins the valley of Kanab creek near the ragged frontal escarpment. The cliffs, seemingly a good thousand feet in height, and the isolated dome-like outliers in front of them present long, smooth slopes of bare rock on which the lines of cross-bedding are beautifully and delicately engraved. The sandstone is so uniformly resistant that its slopes have no well-defined benches such as are usually developed in the weathering of horizontally stratified masses. Joints also have little influence here in guiding denudation. The cliffs have no ornamentation in the way of narrow clefts and slender pinnacles; their contours sweep in curves of large radius, and even the smallest of the outstanding buttes are of imposing size. The sandstone seems to disintegrate chiefly grain by grain, for there is usually little coarse talus at the base of the massive cliffs.

The canyon of Kanab creek through the Jurassic platform is followed by two basaltic flows that seem to proceed from a small cone a few miles to the north. The older flow, thirty or forty feet thick, forms a bench about eighty feet above the present valley floor where we saw it, and ends near the frontal escarpment. The younger flow forms the stream bed, where it is often buried in sand and gravel: it extends about a mile further south than the older one.

Kanab Canyon. — The Triassic platform, with an altitude of 6000 feet and a frontal relief of 1200 feet, is the southernmost of the great terraces by which the descent is made from the High plateaus to the broad upland in which the Colorado canyon is cut. Its frontal escarpment is known as the Vermilion cliffs, of which a characteristic view is given in Plate 2 B. The deep trench worn by Kanab creek through the Triassic platform is locally known as Kanab canyon, not to be confounded with the deeper canyon further south, where the same creek cuts down through the Kanab plateau to the Colorado river in the Grand canyon. The canyon in the Trias is of interest in giving an open section of nearly the whole Triassic formation, and in exhibiting the alternation of aggrading and degrading action by a stream in an arid region.

The Triassic strata are much more variable in texture than the Jurassic. They present many alternations from weak and thin-bedded muddy sandstones to thick, massive, resistant sandstones; and as a result the walls of this canyon are characterized by numerous benches. Cross-bedding is very common, though not on so remarkable a scale as in the Jurassic. The red color is very strong in many beds. It seems at first sight to prevail throughout, but a closer examination shows that some of the cliffs are made of a gray sandstone, whose outcrops are stained by the red wash from the overlying slope.

The uppermost of the red beds are seen in the base of the buttes that front the Jurassic escarpment; the Triassic platform is violently colored with them over large areas. The hue of the ground is so strong and so little concealed by the scanty vegetation that we saw passing cumulus clouds with a distinctly ruddy tinge on their under side, due to light reflected from the colored earth.

Kanab canyon has two terraces of well-stratified alluvium, usually of fine texture and containing lateral unconformities such as are to be expected in the deposits of aggrading streams; yet on the whole the stratification is remarkably even. The higher terrace is eighty or one hundred feet over the stream bed; it is less continuous than the lower one, which stands from forty to seventy-five feet over the stream. The channel below the lower terrace is the work of a series of floods beginning in the summer of 1883; a great part of the alluvium then accumulated along the valley was rapidly swept away. This seemed to be so excellent an example of the spasmodic action of floods in arid regions that I made special inquiry about it, and through the assistance of E. D. Woolley of Kanab secured an account written by his townsman, Herbert E. Riggs; the following is an abstract of the original: —

"At the time of the settlement of Kanab, in 1871, the creek ran at the level of the lower one of the two terraces that are now seen along its canyon. The meadow was about a quarter of a mile wide, with much swamp occupied with flags, bulrushes, rabbit brush and willows. This condition prevailed for about seven miles from the Trias escarpment (Vermilion cliffs) northward up the canyon to where the stream headed, and for about five miles southward, where the meadow broadened as the creek divided and spread over the plain. It was almost impossible to ride a horse up the canyon on account of the mud-holes, quick sands and brushy thickets. The water in the creek was so low that from about May 20 to August 1, the stream would reach the village near the mouth of the canyon only from about day-break to 11 A.M.

In 1874, the meadow in the canyon was thrown open to stock, by which the vegetation was gradually destroyed. The creek was thus concentrated in fewer channels and its flow was increased more than half. Between 1874 and 1883, the canyon floor was fenced up, and the small fields were sowed with red-top and timothy; at the same time, the creek channel was better defined. A road was then constructed through the canyon.

The first great flood came on July 29, 1883. It swept away all of the farms and meadow lands in the canyon, as well as the field crops just south of the village, and scoured out a broad channel beneath the former valley floor. In passing Kanab, the flood was pronounced "as wide as the Missouri river," a rushing stream of liquid mud, bearing cedars, willows, and great lumps of earth. During the winters of 1884 and 1885, the plateaus of the Kanab headwaters received an unusually heavy snowfall; it lay in places ten feet deep on the level and lasted until April. Then as the sun thawed the snowbanks, floods occurred daily for three or four weeks and continued the deepening of the new channel through the canyon. As a result of three years' washing, the stream bed was cut down about sixty feet beneath its former level, with a breadth of some seventy feet, for a distance of fifteen miles."

The meaning of this remarkable change seems to be that canyons in an arid region are aggraded during periods of low water, and degraded at times of exceptional floods. It may be inferred that the duration of the aggrading periods is short in young canyons of relatively steep slope, and that only as the graded condition is approached and reached do longer and longer periods of aggradation come to alternate with spasms of degradation. If this inference is correct, it may be further inferred that the streams of arid climates differ in this respect chiefly in degree rather than in kind from streams in regions of more plentiful and regular rainfall: for the latter are known to clog their channels with bars and shoals at times of low water, and to scour them out during floods; but in the latter case the form of the channel after the flood closely resembles the condition before the flood, while it is greatly altered in the former case.

The scouring of Kanab canyon was checked at two or three points where the flooded stream happened to cut down its channel so near one side of the valley floor as to become superposed upon a previously buried rocky spur of the canyon wall. In such cases only a narrow and relatively shallow notch was cut in the rock, down-stream from which there is now a waterfall; and the channel floor up-stream and down-stream from the fall is now at different levels.

A dam sixty-four feet high has been built across the entrenched stream bed about a mile north of the town of Kanab; an irrigating canal at about the level of the former valley floor is thus supplied with water for gardens and fields in and near the town. Since the erection of the dam, the depth of water in the pond above it has been much decreased by inwashed waste, thus illustrating one of the most serious difficulties — the rapid decrease of reservoir capacity — attendant upon the storage of water for irrigation in the arid region.

Close by the road from Kanab to Fredonia, at the point where it passes through a notch in the Shinarump escarpment, a step fault is seen in the gray Shinarump and the uppermost chocolate Permian beds, with a total uplift of not more than a few hundred feet on the east. The shattered parts of the escarpment has a breadth east and west, across the fault, of about a quarter of a mile, and six or more separate fractures occur within this distance. The apparently vertical slabs between the fractures appear to have been sheared so as to give their strata a dip of about thirty degrees to the west.

THE FAULT AT PIPE SPRING. — The outline map of the district around Pipe spring given in my previous paper (b, Fig. 7) may be here replaced by Figure 4, altered from its predecessor in several details, the most important of which concerns a branch fault with which the Pipe spring monocline is to be associated as a local feature; but full confirmation may now be given to my former conclusion that the Sevier fault continues its course at least ten or fifteen miles further south-southwest and that it is so old that the hard Triassic sandstones of the Vermilion cliffs in the eastern or uplifted (Kanab) plateau block have been worn back at least ten miles more than the same sandstones have retreated during postfaulting time in the western (Uinkaret) block. The latter point is of prime importance from its bearing on the date of the fault. At the time of faulting, it may be provisionally assumed that the Vermilion cliffs were essentially in line on the two sides of the line of fracture. The cliffs on the west of the line are retreating actively to-day and have undoubtedly retreated over a considerable distance since the faulting occurred; but the cliffs on the east of the line, uplifted with the eastern block and therefore more exposed to sapping by the underlying clays, have retreated so that they now stand ten miles north of the retreating western cliffs. This fact alone suffices to throw the date of faulting far back in the plateau cycle.

A fine view of this district is obtained by an easy ascent of the sandstone monocline next northwest of Pipe spring, whence one may see the

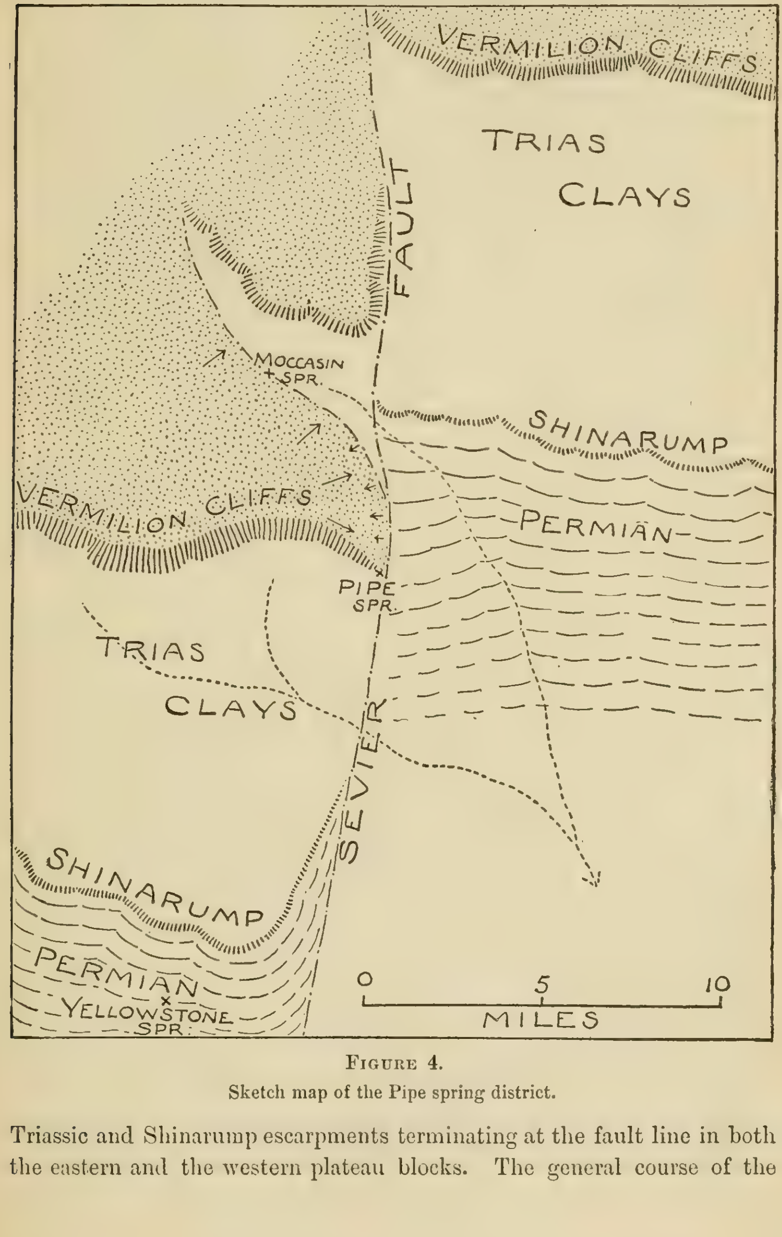
VERMILION CLIFFS
TRIAS
CLAYS
FAULT
MOCCASIN SPR.
SHINARUMP
VERMILION CLIFFS
PERMIAN
PIPE SPR.
TRIAS
CLAYS
SEVIER
SHINARUMP
PERMIAN
YELLOWSTONE SPR.
0
5
10
MILES

FIGURE 4.
Sketch map of the Pipe spring district.

Triassic and Shinarump escarpments terminating at the fault line in both the eastern and the western plateau blocks. The general course of the fault is here a few degrees east of north; its displacement must exceed one thousand or fifteen hundred feet. The bluffs of the great Triassic escarpment — the Vermilion cliffs — are seen coming westward in the eastern (Kanab) plateau block from a point far beyond Kanab: they end at the eastern side of Long valley, about ten miles north of our point of view. A broad and gently sloping graded platform leads forward from the base of the Triassic escarpment to the summit of the lower Shinarump escarpment, whose promontories are seen in profile far east of Fredonia. Although irregular in detail, the general course of this escarpment is held until the capping sandstones are abruptly cut off on reaching the fault line, about two miles away to the north: this is well illustrated in Plate 3 A. The Permian beds were well seen in late afternoon light, their lower and lower layers advancing in faint scarps and well-defined color bands five or more miles south of the Shinarump bluff, until the yellowish super-Aubrey beds appear about the head of lower Kanab canyon where Kanab creek cuts its way down in Kanab plateau, so as to join the Colorado at grade.

Turning now to the western (Uinkaret) block, the Triassic escarpment is seen to end eastward against the fault line at Pipe spring, where its margin with eastward dips lie next to the Permian clays of the eastern block. The Shinarump escarpment of the western block is seen to terminate eastward about ten miles south of Pipe spring, near Yellowstone spring. The relief of the escarpment there is much greater than that of its disconnected eastern fellow, because the graded surface of the plateau plain about Yellowstone spring lies much lower than it does further north, and a much greater thickness of Permian clays is therefore exposed in the strong frontal slope of the escarpment as one passes around its terminal bluff on the way to Yellowstone spring. As with the Triassic escarpment, so with the Shinarump: the retreat of its eastern member is some twelve miles in excess of that of its western member: and the latter must to-day be retreating with considerable rapidity, if one may judge by the fresh surface of the weak Permian clays under the capping sandstones. It is in these bluffs that one may see the slight unconformity of Shinarump on Permian noted by Dutton (b, p. 44, 80), and here illustrated in Figure 5.

THE MOCCASIN FAULT. — The eastern border of the Triassic upland back of Pipe spring is indented by a flat-floored, mile-wide valley heading to the northwest. The valley may be named after Moccasin spring on its western side. The strong Triassic sandstones are locally bent down so as to dip 10° or 20° northeastward as they descend toward the valley on its southwestern side; and it is this local bending of the sandstones that produces the monoclinal flexure of Pipe spring. The sandstones on the further side of Moccasin valley are horizontal close to the main Sevier fault, except for the gentle northward dip that prevails through the whole region.

The floor of Moccasin valley — see Plate 3 A — is broadly covered with wash, but near its northeastern side the weak blue clays of the lower Trias are seen near the base of the enclosing escarpment. It is therefore concluded that the valley is underlaid by these weak beds, whose easy removal has caused the retreat of the Trias to the northeast. A branch fault must be here inferred, curving northwestward from the main fault along the southwestern side of Moccasin valley with a heave of twelve hundred feet or more on the northeast. The further end of the fault did not seem more than five or six miles away to the northwest, but it was not traced.

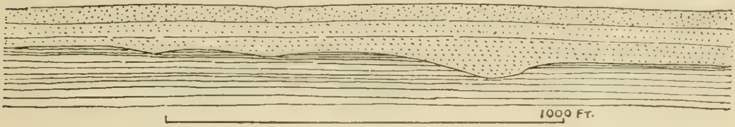

FIGURE 5.

Diagram of the unconformity at the base of the Shinarump.

Moccasin spring, like Pipe spring, supplies water enough for a small ranch. The two springs are about three miles apart; they are alike in flowing out at the eastern base of the sandstone monocline, where these permeable strata are faulted against impermeable clays; Triassic clays in the first case, Permian clays in the second.

EROSION IN THE PIPE SPRING DISTRICT. — The abundant erosion in the Pipe spring district since the production of the Sevier fault has had three characteristic but different effects, each controlled by the structure. First, all the outcrops of corresponding strata on the two sides of the fault are out of line by ten or twelve miles; this distance measuring the *excess* of escarpment-retreat in the uplifted eastern block over that in the western block, as has been pointed out. Second, where weak members of different horizons are brought together on opposite sides of the fault, the land surface is worn down to a relative lowland of even grade across the fault line; that is, the fault is there topographically extinguished. This is well shown just south of Pipe spring, where the lowland of the Triassic clays west of the fault line is drained to the lowland of Permian clays east of the fault, the drainage flowing from the depressed to the elevated block. Third, where resistant members are faulted opposite to weak members, the resistant member forms an upland on one side of the fault overlooking the lower land eroded on the weak member on the other side of the fault; and this entirely independent of the heave and throw of the displacement. Thus the Triassic upland of the eastern block overlooks the lower land of Long valley, which I presume is eroded on the weak upper Trias; and the Shinarump of the eastern block overlooks, from a modest height to be sure, the lower land of the weak Triassic clays in Moccasin valley. In both these cases, the upland of resistant rocks is in the uplifted block. On the other hand, the Triassic upland of the western block overlooks lower lands of lower Triassic and Permian clays east of Pipe spring in the eastern block; and the strong Shinarump upland by Yellowstone spring overlooks the broad lower land of the lowest Permian layers in the eastern block. In both these cases, the effect of the fault is topographically reversed: the upland of resistant rocks is in the relatively depressed block; the relief is in spite of the fault and is evidently due entirely to erosion.

It follows from what has just been said that whatever arrangement of drainage may have been for a time consequent on the topography initiated by faulting, that arrangement is now replaced by a new one adjusted to the faulted structures. Stream beds and the general "wash" of the surface frequently cross the fault line, as often from the thrown to the heaved side as from the heaved to the thrown side. An example of this kind was described in my previous report (b, p. 128) from the neighborhood of Pipe spring, of special interest from the activity with which the "wash" that flows eastward across the fault from the thrown to the heaved side is undercutting and gaining area from the higher-lying westward wash. The divide between the two drainage areas is a low east-facing escarpment, known as Cedar ridge, now migrating westward and at a relatively rapid rate. It was seen only from a distance in 1900, but was visited in 1902. The varicolored lower Trias shales are here much better exposed than at any other point in the district. There can be no question that my previous interpretation of this divide was correct, and that the occurrence of such a divide draining towards and migrating away from the heaved block, is entirely inconsistent with a recent date for the fault at Pipe spring. There can therefore be no doubt that the Sevier fault hereabouts as well as at Upper Kanab is of considerable antiquity: it cannot be dated in the canyon cycle, but belongs rather early in the preceding plateau cycle.

The fifty miles of fault line between Upper Kanab and Pipe spring have not yet been closely described in any geological report or article. The effect of the fault and of subsequent erosion on the White cliffs of the Jurassic sandstones may be commended as offering excellent subjects for a thesis in structural geology in a region of great scenic attraction.

Connection of Sevier and Toroweap Faults. — It is on account of the second one of the above-mentioned effects of erosion that the southward extension of the Sevier fault to the Toroweap is not easily traced. South of the Shinarump escarpment by Yellowstone spring, the throw of the fault seems to decrease somewhat from its measure further north: for in Antelope valley (see sheet XXII, Dutton's Atlas) the middle Permian clays on the west seem to stand against the lower Permian clays and the yellowish super-Aubrey beds on the east. But in this district of weak strata there is little or no cause for the fault to express itself in the topography. It is probable, however, that a general view of the district, such as might be obtained from the southermost Shinarump bluff, would disclose a dislocation of the color belts by which the gray and reddish clays and the yellowish calcareous beds are often revealed on the surface.

Still further south on the eastern side of Wonsits plain, a low bluff of super-Aubrey beds overlooks what I took to be Permian beds on the west, as mentioned in my previous essay: the fault probably passes near the base of this bluff, which lies near the final letter N of "Wonsits plain" on sheet VII of Dutton's Atlas. The geological coloring of this sheet gives a different interpretation from the one just suggested.

Still further south, about twenty miles beyond Yellowstone spring, the existence of the fault and a not-recent date for it are indicated by the attitude of the extensive lava beds that are there spread over the uplands on both sides of the inferred fault line. On the southeast, the lavas appear to lie for the most part with low edges on an upland of super-Aubrey or Aubrey limestone, in which relatively narrow valleys are opened where the lavas are absent. On the southwest, the lava beds, apparently at the same altitude as those on the southeast, form mesas with well-scarped edges that surmount slopes of lower Permian or super-Aubrey beds. The difference of horizon is not many hundred feet, but it seems to show that the lavas were spread out on a broad peneplain formed late in the plateau cycle by the far advanced erosion of the dislocated plateau blocks, as in Figure 6. To-day the peneplain is preserved only where it consists of resistant Aubrey beds, or where it is covered with lavas. Where the peneplain was underlaid by weak Permian beds, its surface has now been worn away to a lower level in the Uinkaret block, and in the Kanab block also somewhat farther north. Truly, the fact that different horizons are here covered by the lavas might be interpreted as meaning that the western lavas were poured out before any fault had occurred and when the land surface was at a Permian horizon; that the eastern lavas were poured out after the land surface had there been worn down to an Aubrey horizon; and that a recent fault, passing between the two lava-covered areas, had raised the eastern lava field to the same level with the western. But this conclusion is extremely improbable because it is encumbered with the necessity of attributing to the lavas a highly specialized recognition of two areas that were afterwards to be divided by a fault, and of two different levels that were afterwards to be brought into accord by faulting.

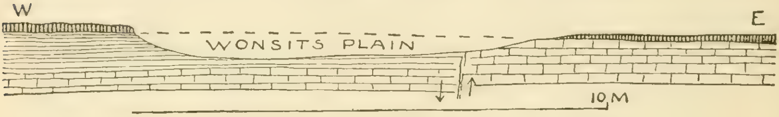

FIGURE 6.

Sketch section across Wonsits plain.

There is still a distance of some ten or fifteen miles from the lava beds to the more open part of Toroweap valley, through which the fault has not been traced. When this district is viewed from the top of Mt. Trumbull, there seems to be a west-facing bluff of Aubrey or super-Aubrey beds extending north from the east side of the valley past certain lavas in the valley head toward the low bluff of super-Aubrey beds, above-mentioned as overlooking Wonsits plain. This district is not easily examined in summer on account of the scarcity of springs. It might be studied earlier in the season when certain water pockets can be more safely depended upon, and I do not doubt that the fault might then be almost continuously traced into the Toroweap.

THE TOROWEAP FAULT AT THE GRAND CANYON. — As one descends into the broad Toroweap valley by the trail that leads down the slope of a grand lava cascade three miles southeast of Oak spring, it is easy to see that the eastern wall of the valley rises higher than the western, although both are rimmed with upper Aubrey limestone; and that the red lower Aubrey beds are abundantly exposed along the lower half of the eastern wall for fifteen or more miles north of the canyon, while these beds make a much smaller part of the western wall. This evidence of a fault along the valley is abundantly confirmed at the canyon, where the dislocation in the southern wall is clearly seen in the grand view from Vulcan's throne, as Dutton has told (b, p. 93). In my excursion of 1900, our party had but a few hours at this point, and during much of that time I was so overcome with the heat that it was impossible for me to make any critical observations. During the past summer, much better opportunity for studying this most interesting locality was gained by camping over two nights, from July 21 to 23, on the esplanade just east of the fault line; the only drawback on this occasion being that our stay there was during a period of haze brought by the southwest winds, and accompanied by sultry nights as well as excessively hot days. We carried water for our own needs from Oak spring, and watered our horses at a muddy reservoir made by the stockmen just north of Vulcan's throne.

The point on which I previously felt constrained to differ from the conclusions presented in Dutton's report concerned the date of the Toroweap fault relative to the erosion of the canyon. It still seems necessary to regard the fault as for the most part of earlier origin than the canyon, because the valleys that follow the line of dislocation both north and south of the canyon are widely opened. Had the fault been produced after the erosion of the esplanade, that is, at so recent a date that even the vigorous Colorado has since then had time to carve only a narrow canyon, it would have been quite impossible for weak and intermittent wet-weather streams to have, in the same brief period, carved broadly open valleys, two or three miles wide, along the fault line. So late a date for the fault therefore makes it necessary to suppose that the broad north and south Toroweap valleys had been eroded during an earlier period, identical with that in which the esplanade was developed, and that the Toroweap fault line subsequently followed the course of the valleys: an extremely unlikely occurrence. It is much more probable that the greater movement of the fault antedated the erosion of the north and south Toroweap valleys, and that their location was in some way dependent on the fault.

On the other hand, a relatively recent additional movement of a hundred or more feet is clearly indicated by the dislocation of a lava bed in the floor of the south Toroweap valley close to the canyon rim, as described by Dutton (b, p. 94). A corresponding movement is indicated on the north of the canyon in the gulch between the eastern base of Vulcan's throne and the west-facing scarp of the esplanade, as in Figure 7. Near the base of the esplanade scarp there is a bench of firm black lava, which has no fellow on the west side of the gulch where the slope consists wholly of tuff. Some of the tuff stands up in little ridges bordering the base of the ash cone and seems to have a steep dip to the west. The vertical displacement here indicated by the lava bed may be one hundred feet or more. A northward continuation of this subrecent movement is suggested by a low west-facing lava scarp that may be traced for a mile or more north of Vulcan's throne on the eastern side of Toroweap valley floor. A still more recent movement is indicated by a small but distinct scarp, about twenty feet in height, that traverses a gravel wash on the east side of the south Toroweap valley, somewhat east of the main fault line. This scarp was seen in a sunset view from Vulcan's throne, when in spite of its distance of about three miles, the low western sunshine brought it distinctly to sight. A significant amount of faulting must therefore be recognized as having occurred near the canyon at least, after the esplanade had been formed and after lavas had been poured on its floor. On the other hand, there seems to be no sufficient reason for regarding the chief movement on the Toroweap fault, amounting to six hundred or seven hundred feet according to Dutton, as having occurred in the canyon cycle. Analogy with the neighboring great faults would suggest an earlier origin in the plateau cycle; this opinion is not at all contradicted by the dislocation of the esplanade, and it is supported by the considerable width attained by the Toroweap valleys, north and south of the canyon, as explained in my earlier article (b, p. 143, 184).

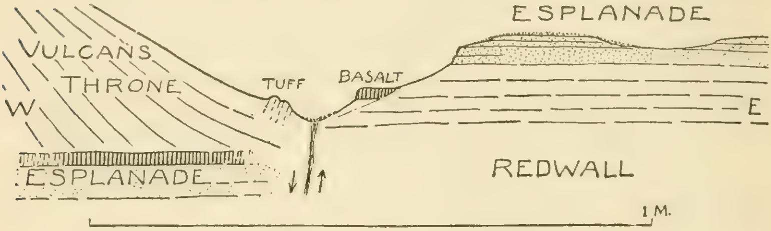

FIGURE 7.

Sketch section at Vulcan's Throne.

The decrease of the displacement northward along the valley reported by Dutton (b, p. 93) is probably more apparent than real; the heavy lava flows on the valley floor would tend to conceal the escarpments by which the fault is so clearly revealed at the canyon.

Camping on the Esplanade.

General Features of the Esplanade. — The experience of camping in the esplanade was mentally impressive rather than physically enjoyable. The noon hours were oppressively hot, and even the nights were too sultry for refreshing sleep, but the latter discomfort was probably only a temporary element associated with the haze brought by the enervating southwest wind. The scenery is marvellous. The views from the salient corner of the esplanade next to the fault, and from the ash cone, Vulcan's throne, well repaid the discomfort that they cost.

The floor of the esplanade is rather even when taken all together, but it possesses a considerable relief in detail. It consists in about equal parts of clean-swept, cross-bedded, red sandstone — the "esplanade sandstone," or uppermost member of the red-wall group — and of stony, dusty waste in which an interesting desert flora finds root. Small rock basins or water-pockets are plentiful: many of them contained an inch or so of lukewarm, unsavory water at the time of our visit. A light thunder-shower — one of many that started down from the clouds — reached the esplanade at noon, July 22, making the bare rocks glisten for some distance up the canyon; but there was "not enough water to run," as the local phrase has it. Distances are not easily estimated because the dimensions of the enclosing cliffs are so much greater than those of the hills that one is accustomed to in regions of moderate relief. A point that at first sight seems within reach of an easy stroll demands a long walk before it is reached. The terrace of bright red sandstone — the "basal Aubrey sandstone" overlying the "esplanade sandstone" — that skirts the eighteen hundred foot Aubrey cliffs as a small detail of their imposing slope grows to a high bench when one comes to climb it.

The general floor of the esplanade declines gently to the rim of the inner canyon; one must walk along the very edge of the great bench to see down to the river, nearly three thousand feet below. Truly this enormous gorge is only half as deep as the whole canyon in the Kaibab; but there the eye wanders bewildered over the superabundant elaboration of gigantic lateral spurs and ravines, while here the impressive simplicity of form, as shown in Plate 4 A, lends great dignity to the prospect. It is certainly an unforgettable experience to stroll at leisure along the rim of the canyon, now looking across the esplanade to the great cliffs that rise to the plateaus, now looking down to the tawny river, all in the glare of burning sunshine except for the deep shadows on the south wall of the canyon.

At certain points one may see the river for the better part of a mile, but the bends in its course soon carry it out of sight. Its most notable features are: — an apparently graded flow, the absence of flood-plain strips, foam-like patches of whitish sand along the water's edge, a slope of talus for several hundred feet over the river banks, and the projection of a delta fan more than half across the channel from the first large lateral ravine in the northern esplanade east of the fault line. This ravine joins the canyon at grade, although its drainage area from an amphitheatre in the Aubrey cliffs over the esplanade is not a tenth, perhaps not a twentieth of the Toroweap area. The slope of the southern wall of the canyon, measured on a photograph, is close to 60° : about a quarter of the wall consists of steeply graded, talus-covered slopes at an angle of 35° ; the remainder is made up of rock-faced cliffs, with slopes of 70° or more. There are five chief cliff belts, the strongest of which is on the upper red-wall limestone with a nearly vertical height of six hundred feet.

The salient corner, where the northern esplanade is cut off by the Toroweap fault, affords a superb view of the effects of this dislocation. The floor of the southern esplanade is foreshortened in the view from a point at its own height; it is in places bare, in places dotted over with cedars like a thinly planted orchard as in Plate 4 B. The extension of the esplanade west of the fault on the north side of the inner canyon is here concealed by Vulcan's throne; but it is well shown on the south side of the canyon two hundred or three hundred feet (according to the topographic map of the district) below its counterpart east of the fault. The descent from one level to the other is made partly by an abrupt scarp of the esplanade sandstone, and partly by a slope of the weaker beds that lie between the esplanade sandstone and the red-wall limestone. Directly at the base of the slope lies the sheet of lava by which the floor of south Toroweap valley has been held up; the lava west of the fault being just about at the level of the cliff of red-wall limestone (under the esplanade sandstone) east of the fault, as is clearly shown in Plate 5 A. It was an immense satisfaction to see all this from so suggestive a point of view as the corner of the northern esplanade. There I spent two memorable morning hours, taking refuge beneath overhanging ledges under the corner when the sunshine became unpleasantly strong, and then slowly retreating to a larger rock shelter near our camp, a mile back, for the hot hours of noonday.

The View from Vulcan's Throne. — The ascent of Vulcan's throne in the late afternoon afforded a much more comprehensive view than that of the morning. The ash cone to which a classic name has been — somewhat unfortunately — attached is marked on Dutton's topographic map (b, Atlas sheet VIII.) as having an absolute altitude of 5100 feet: it is therefore about six hundred feet higher than the lavas on the esplanade west of the fault in the Uinkaret block, six hundred feet higher than the esplanade next east of the fault in the Kanab block, and 3500 feet above the river whose channel lies a mile south of its summit; but it is 1200 feet below the upland of the Kanab plateau block on the northeast. When looking up the canyon from the cone, one has the view that has become famous in Holmes's wonderfully effective drawing (Dutton, b, Atlas sheet VI.); the esplanade stretching far eastward, enclosed by great cliffs and spurs of Aubrey, north and south, and trenched along its middle by the inner canyon. Holmes's graphic interpretation of the esplanade floor gives the impression of a greater number of evenly graded and waste-covered hills or mounds than I noted in the actual view, where the proportion of bare rock is unusually large: the softest forms are near the faulted edge of the northern esplanade, where a moderate amount of lapilli from Vulcan's throne cloak the surface.

The northward view shows the broad floor of the Toroweap valley, enclosed by promontories of normal Aubrey cliffs along the margin of the Kanab plateau on the east, and by Aubrey cliffs cloaked with a marvellous series of lava cascades from the Uinkaret plateau on the west; all this being portrayed with great fidelity in another of Holmes's drawings (Dutton, b, Atlas sheet V., lower view). This valley is, like its southern counterpart, exceptional in following a fault, the other drainage lines of the region being as a rule indifferent to faults. It is however very possible that, at the time when the faults occurred in the plateau cycle, drainage lines were instituted consequent upon the slopes of the dislocated surface of that time, and that some of the lines followed the depression along the junction of each pair of plateau blocks, as has been suggested in the account of the Sevier fault at Upper Kanab. In most cases these stream lines were broken up as the adjustment of streams to structures took place, as in the Pipe spring and Upper Kanab districts; but in the Toroweap district, where the postfault erosion was probably concerned for the most part with Permian and lower Trias clays (the Shinarump being the only resistant member of this part of the series), the stream consequent on the faulting seems never to have been tempted from its original course.

The high floor of the Toroweap must certainly be referred to the floods of lava that have been poured into it, as was suggested in my previous essay (b, p. 189) and not to weakening of stream action due to change of climate. The deep incision of several neighboring lateral canyons of no larger or even of smaller drainage area than the Toroweap, but unobstructed with lava, leaves no room for doubt on this point. The same explanation must apply to the high floor of the South Toroweap valley, for although the lava there is of relatively small area, it is precisely in the right situation — at the mouth of the valley — to be most effective in retarding erosion. It is the breadth of the two Toroweap valleys that at first seems abnormal; but I am convinced that the difficulty here is more apparent than real. The breadth of these valleys, like that of the esplanade, is practically independent of the depth to which erosion has proceeded beneath the esplanade sandstone. The esplanade level once being reached by the valley stream, the widening of the valley goes on rapidly because the weak lower Aubrey beds waste easily and sap the upper Aubrey cliff at the top of the valley walls. The upper walls of the main canyon would not be less widely separated than they are to-day if during the actual lapse of time in the canyon cycle, the river had never cut the inner canyon below the esplanade: the Toroweap valleys would be hardly wider than they are even if their streams had cut down to grade with the main river, without hindrance from lava floods; good warrant for the latter inference being found in the rough equality of width between the upper Aubrey cliffs in the deep Cataract canyon (a southern branch of the Colorado) and in the shallow Toroweap (see Dutton, b, Atlas sheet VIII.).

It may be noted in passing that at a distant future stage of erosion, the existing re-entrants in the Aubrey cliffs on the west side of the Toroweap, down which the great lava flows have cascaded from the cones on the Uinkaret, will be converted into salients; for the Aubrey buttresses between the lava cascades will pretty surely weather back faster than the cascades themselves, inasmuch as the cascading lavas cover the weak lower Aubrey beds on whose weathering the retreat of the strong upper Aubrey so largely depends. In that distant future time, this district may therefore be expected to present, in horizontal plan, an exemple of inverted relief, — cliff re-entrants changed to cliff salients, — with which we are so familiar in vertical profile where ancient lava-flooded valleys have been transformed into existing lava-capped table mountains.

The view of south Toroweap valley from Vulcan's throne is more extensive than that from the corner of the esplanade (Plate 5 A). It is partially shown in one of Holmes's drawings (Dutton, b, Plate XVIII.). The further end of the valley turns gradually from south to southwest. The lower western wall curves out of sight and the higher eastern wall bends round so as to close the view; hence the fault must turn westward with the valley. The lavas of the south Toroweap were poured out before the inner canyon had attained nearly its present depth, yet not until the valley had been eroded several hundred feet beneath the esplanade sandstone; for the lava rests on a considerable thickness of ash (not distinctly shown in Holmes's drawing referred to above) exposed in the southern wall of the canyon, and yet the lava surface is at the west-esplanade level. The outburst of the lavas must have been long after the first and greater movement of the Toroweap fault, but the lava sheet is now broken by the recent smaller movement, apparently on or close to the old surface of fracture, as has already been stated. A short lateral gulch of the main canyon, apparently gnawed back along the new fault, divides the nearer part of the lava sheet into an eastern (higher) and a western (lower) portion. A small ash cone surmounts the latter; it has been partly undermined by the widening of the gulch. The dikes that rise in the wall of the canyon, as if to feed this cone, figured in Dutton's monograph (b, p. 96), confirm the date above suggested for these local eruptions with respect to the erosion of the inner canyon; most of the depth of the canyon must have been eroded after the dikes were intruded. Two other ash cones are seen further south: one is about a mile from the canyon, close to the scarp by which the dislocation of the esplanade can be traced far along the valley; the other is a mile or more beyond, on the lower Aubrey slope on the east side of the valley. Two small cones stand on the south esplanade, about a mile and a half east of the fault line. They are seen in Plate 4 B. They seem to be due to eruptions after the erosion of the canyon had nearly reached its present stage, for their lava flows into the head of a neighboring ravine whose length could not have been gained until the canyon was deeply incised. It seems remarkable that the ascent of lava to these cones should have so completely disregarded the opportunity of finding a vent in the canyon wall. There is no record that the south Toroweap has been visited by a geologist: all that is known of its structure depends on observations from the north side of the canyon, at distances of several miles. The southern end of the fault which guides the valley has not been closely determined.

The view westward down the canyon, Plate 5 B (see also Dutton, b, Atlas sheet V. upper view) is very unlike the eastward view. The normal esplanade of the southern Uinkaret, enclosed by Aubrey cliffs, is seen south of the canyon; it is cleft by a ravine that is fed with wet-weather wash from an Aubrey amphitheatre of moderate dimensions, very much smaller than the south Toroweap; yet this ravine descends rapidly and joins the river in the canyon bottom at grade. In this respect, it resembles the ravine in the northern esplanade east of the fault, already described. The lava-covered esplanade of the Uinkaret is seen north of the canyon: its enclosing Aubrey cliffs are almost completely hidden under the huge floods of lava that sweep down from a throng of vents on the plateau, and the floor of the esplanade is banked up to form an inclined plane. The lava cascades follow re-entrants of the esplanade border into the canyon, but are not distinctly traced all the way to the river. The cascades have a slope of 20° or 30°, while the upper half of the southern canyon wall has an average slope of 40° or 45°. The difference may be due to the abrasive or melting action of the lavas as they poured over the rim of the esplanade. The general effect of these unequal slopes is to give the canyon here an unsymmetrical cross-section. It is possible that the asymmetry may have been increased by the action of the lavas in pushing the river against its southern bank, and thus making it undercut the southern wall more actively than the northern; for the lower part (1500 or 2000 feet) of the wall has a slope of 65° on the south and rather under 60° on the north. The river itself is seen for a long mile of apparently placid flow: it is here as further east bordered by talus rather than by bare rock; patches of whitish sand lie on the banks here and there, and a few fan-deltas project from side ravines a third or a half way across the river. Beyond the terminal corners of the north and south esplanade of the Uinkaret block in the middle distance, there are glimpses of the Shivwits plateau, dropped a thousand feet from the corresponding upland surface of the Uinkaret. The view is closed by a long mesa surmounting the Shivwits, apparently a lava-capped mass of Permian beds.

The Hurricane Fault.

Previous Statements. — The Hurricane fault is, according to Dutton, like the Toroweap fault of modern date, younger than the beginning of the canyon cycle: the evidence for this conclusion being the relatively small retreat of the great cliffs of Aubrey limestone known as the

"Hurricane ledge" from the fault line. A more remote date seemed to me proved by the great recession of the Shinarump and Triassic cliffs in the higher (Uinkaret) block east of the fault than in the lower (Shivwits) block west of it: I was indeed led on my first excursion to believe here as elsewhere that the faulting had taken place long before the occurrence of the uplift by which the canyon cycle was introduced, so that the obliteration of the initial relief due to faulting and the general baselevelling of the plateau area had been accomplished before the erosion of the canyon was begun. According to this view, the Hurricane ledge as a topographic feature is not the direct result of faulting, but the result of renewed erosion on a faulted, baselevelled, and uplifted mass.

The work of last summer showed, in effect, that both these suppositions are in a measure correct; for the Hurricane fault has suffered repeated displacements, a long interval having elapsed between its earliest and latest movements. The relief produced by the earliest displacement was demonstrably obliterated over a large area before the later displacements occurred: while the relief produced by the latest displacement is still in certain places but little affected by erosion.

The remote date of the earliest displacement is proved by the great amount of erosion that has taken place after it. This is shown first by the retreat of the escarpments in the uplifted (Uinkaret) block several miles in excess of their retreat in the other (Shivwits) block, and second by the continuity of a level lava flow resting on an even surface of erosion that crosses the fault line. The first line of evidence was presented in my previous essay (b, p. 142–148); the second may be introduced here.

THE SECTION NEAR COAL SPRING. — A ride of some ten miles west-southwest of Mt. Trumbull carries one to a point near Coal spring, about eighteen miles north of the canyon, where the western escarpment of the Uinkaret plateau is capped with a lava bed, whose essential features are shown in the front block of Figure 8. The escarpment at this point is of moderate slope, quite different from its usual bold form; and instead of consisting of a cliff of upper Aubrey above a talus-slope of lower Aubrey, as is the case for most of its length further north, the escarpment here shows abundant outcrops of gray and reddish Permian clays, one thousand feet or more in thickness.

These Permian beds evidently belong in the western or Shivwits block, where they follow normally above the yellowish super-Aubrey beds which to-day constitute so much of the surface of that block below the

Hurricane ledge. The Permian beds stand, however, opposite to the lower and upper Aubrey beds in the Uinkaret block. The Hurricane fault in this locality must therefore pass underneath the lava bed, and its throw must be at least a thousand feet. The effect of faulting, without erosion, is shown in the back block of Figure 8. At a later time when the lava was erupted, erosion of the faulted mass must have progressed so far that the Permian clays had been largely removed from the Uinkaret block hereabouts, while they still largely remained on the Shivwits, so as to make a level surface across the fault line on which the lava was poured out, as in the middle block of Figure 8. It is evident that such a correspondence of level across the fault on beds of very unequal resistance could have been produced only by long-continued and widespread erosion when the region stood much lower than now. This structure may therefore be taken as another point in the evidence that demands two cycles of erosion (the plateau cycle and the canyon cycle) for the physiographic development of the region. The chief movement of the Hurricane fault must consequently be dated far back in the plateau

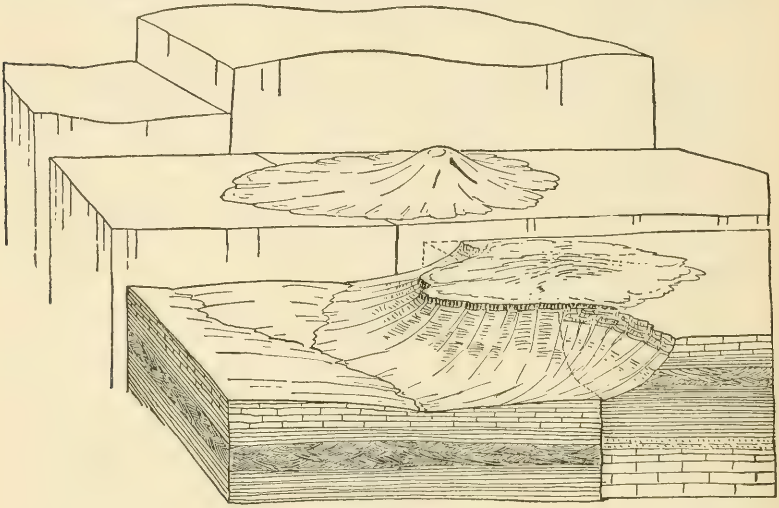

FIGURE 8.

Diagrams to illustrate the history of the Hurricane fault near Coal spring. The back block shows the effect of faulting without erosion. The middle block shows a volcano erupted near the fault after the faulted mass had been worn down to a peneplain. The front block gives a generalized view of existing conditions produced by uplift and erosion of the middle block.

cycle of erosion, and this makes the Hurricane fault as old as the Sevier-Toroweap fault.

The point from which these observations were made is not surely identified on Dutton's map, but it is probably the basalt-capped bluff at lat. 36°22½′, long. 113°16½′, on Atlas sheet VIII. The lava-capped Permian slope lies just beyond a ravine next north of the bluff, from half a mile to a mile distant, and quite unmistakable as to structure; but on Dutton's map the corresponding slope is colored to show a slanting sheet of basalt, and it is especially on this account that I am uncertain as to its identification.

An important corollary of the above conclusion regarding the date of the fault is that when a general uplift of this broadly eroded region took place, introducing the canyon cycle, the renewed work of erosion was not limited to the carving of the canyon alone; it must have included the sweeping of weak strata such as the Permian clays from wide areas, as was indicated in my previous essay (b, p. 136). If the history of the region is thus correctly interpreted, the present inequality of level between the Shivwits and the Uinkaret plateaus is only very indirectly the result of faulting. It is directly the result of erosion by which a heavy mass of weak Permian clays has been quickly worn off of the Shivwits plateau, while only a small amount of carving has been accomplished in the resistant Aubrey beds of the adjoining Uinkaret plateau. The Hurricane ledge is therefore a cliff developed by erosion on a faulted mass, as in the foreground of Figure 8; it is not a "fault cliff" in the proper sense of that term, except in so far as modern faulting, late in the canyon cycle, may have increased the escarpment of erosion. We were unable to recognize any such element in the view from the bluff near Coal spring: if modern movement has taken place in this locality, it can have hardly occurred on the ancient surface of dislocation, for the lava bed that crosses the fault line did not seem to be broken.

Renewed movement has, however, taken place elsewhere in association with the Hurricane fault. Dutton states that certain modern lava beds are somewhat dislocated on a branch of the Hurricane fault in Quantoweap valley not far north of the canyon (b, p. 116, 117), just as they are at the mouth of south Toroweap valley. But much greater modern movement, long after the strong ancient movement, has taken place seventy miles north of the canyon where Virgin river crosses the fault line and beyond, as will be fully set forth in the report by my companions, Messrs. Huntington and Goldthwait.

The great contrast in the resistance of different rocks to erosion may be taken either as a postulate of this interpretation of the Hurricane ledge, or as a consequence following from it: in either case, the explanation of the plateau topography involves the recognition of two groups of rocks, very unlike in their resistance to erosion, so that a period of time which only serves for the erosion of a narrow canyon by a strong river in the more resistant strata, suffices for the stripping of the less resistant strata from great areas by unconcentrated subaerial weathering and by the washing of occasional wet-weather streams.

THE SECTION NEAR ANTELOPE WASH. — The Hurricane ledge and its fault would well repay attentive study along the western border of the Uinkaret plateau; but springs are so few and far between along its course that it is difficult of exploration. We rode out to its edge at two other points north of the lava-capped spur near Coal spring: one was near one of the northwestern volcanoes of the Trumbull area, an isolated cone about thirty miles north of the canyon; the other was a mile south of the trench cut by Antelope wash. From the first of these points, we saw a high lava-capped Permian butte rising over the Shivwits plateau about three miles west of the Aubrey strata exposed in Hurricane ledge. This seems to confirm the conclusion reached near Coal spring; for the lava-cap suggests that the underlying Permian strata have an approximately level surface at an altitude that is far above baselevel to-day, but which must have been relatively near baselevel before the lava was poured out; otherwise the Permian surface could hardly have been worn so flat as it seems to be. A local complication was here noted at the base of the ledge, strongly suggestive of recent faulting, but we had no time to descend and study it.

The view northward showed at a distance of ten or fifteen miles a curious offset in the fault whereby a splinter of upper Aubrey at the edge of the Uinkaret bends down and descends southward to the Shivwits level, as is roughly shown in Figure 9.

The view from the Hurricane ledge near Antelope was exceptionally interesting in its display of brilliant red Triassic clays and sandstones in the ten miles of lower land between the base of the ledge and the Virgin river east of St. George, and in its exhibition of lava-capped Permian mesas on the northern terminal slope of the Shivwits plateau. The geological wonders of the scene were rivalled only by its exceptional barrenness. Not the least notable feature was the suggestion of extreme heat given by the vivid colors of the Trias as well as by the ominous blackness of the lavas. A muddy stream was still running down the channel of the wash from the thundershowers of the afternoon before. The district was plainly enough not one to tempt exploration in midsummer, but as it all lay within ten miles of Virgin river it might be comfortably examined in the spring or fall months. It will be briefly described by Messrs. Huntington and Goldthwait, but it would repay much more elaborate treatment than they were able to give it.

The Hurricane ledge near Antelope probably owes a good part of its height to modern movement on or near the plane of an ancient fault. The same statement may be made with more confidence of the point a mile south of Virgin canyon where my party descended the ledge in 1900, and of the point three miles north of the same canyon where we came down the wagon road from Virgin city to Toquerville last summer; but all this will be described by my student companions.

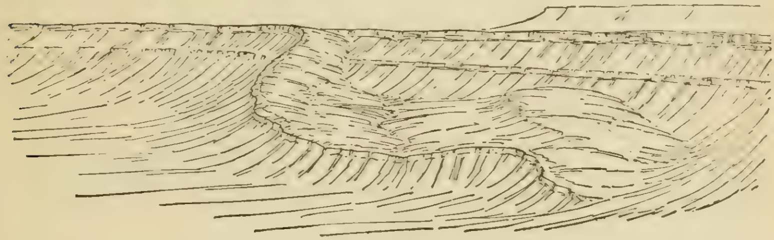

FIGURE 9.

Diagram of a rock-splinter on the Hurricane fault.

The Topography of the Colorado Canyon.

THE CROSS-SECTION OF THE CANYON. — The form of the Colorado canyon as seen in cross-section seems everywhere responsive to the resistance of the rocks in which it is carved. The river appears to have entrenched itself beneath the rising plateau with relative rapidity and continuity, there being no benches independent of resistant strata, and therefore no proof of pauses during the uplift of the region. The esplanade that forms so striking a feature of the canyon in the Uinkaret and in the western part of the Kanab plateau is accordant with the upper surface of the heavy sandstones that overlie the red-wall limestone in which the inner gorge is there cut. As was pointed out in my previous essay, the topographic maps of the canyon show a gradual disappearance of the esplanade eastward, and in the Kaibab portion of the canyon the stratigraphic equivalent of the esplanade is seen only in a series of thoroughly dissected red-wall spurs. The reason previously suggested for this change is the weakening of the upper Tonto strata as they extend eastward. In the Uinkaret they are strong enough to act as cliff-makers with the overlying red-wall limestones; in the Kaibab they are a heavy series of relatively weak gray and yellowish shales by which the red-wall cliffs are undermined. The single bench shown in the cross-section of the canyon near Toroweap valley, Figure 10 A, is therefore replaced by two benches in the canyon of the Kaibab section, Figure 10 B, the lower bench being capped by the Tonto sandstone and cut by the narrow gorge in the fundamental crystalline rocks; the upper bench being held by the red-wall limestone. The gray slopes of Tonto shales between the benches are notable features of the canyon in the Kaibab.

It is interesting to note that in the eastern part of the canyon in the Kaibab, which I had opportunity of seeing in the superb view from Bissell's point in 1901, the cross-section is still further changed, as in Figure 10 C; here the basal crystallines give way to relatively weak Algonkian strata, and the bottom of the canyon is a well-opened valley with some strips of flood-plain bordering the river here and there. Further up the river, where the east Kaibab monoclines bend down all the basal crystallines and Algonkians beneath the canyon bottom, the red-wall limestones close in again to form the Marble canyon. Still further up at Lee's ferry, where the red-wall limestones dip underground and bring the weak Permians and lower Trias down to the river, the canyon is for a short distance replaced by an open valley. Then the hard Trias cliffs close in to form Echo canyon. The accordance of form and structure is thus found to be so close that it seems inadmissible to accept the esplanade, a local feature in the western part of the canyon, in proof of a pause in the general uplift of the whole region. Had such a pause occurred, there should be other evidence of it besides the esplanade.

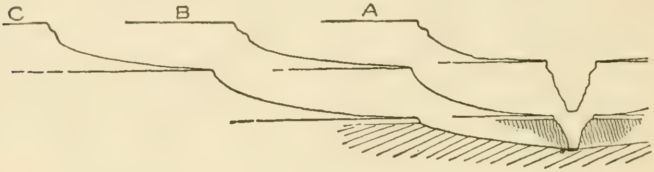

FIGURE 10.

Sections of the Colorado canyon at the Toroweap (A), in the middle Kaibab (B), and in the eastern Kaibab (C).

Amphitheaters in the Canyon Walls. — Many of the sharp spurs into which the red-wall cliffs are now cut in the Kaibab portion of the canyon are separated by amphitheaters of remarkably regular curvature. The explanation for these notable forms that occurred to me after having seen them in 1900 (b, p. 178) was fully confirmed in my excursion of 1901.

The amphitheaters occur only where the area whose drainage falls from higher levels over the cliffs is so small that it does not supply any large streams even in wet weather. In the absence of large streams, all parts of the red-wall cliff in each amphitheater now retreat, and indeed for a long time have retreated, at about equal rates. For example, the red-wall cliffs of the amphitheaters, G and J, in the spur of Figure 11, receive drainage only from the short slopes of isolated lower Aubrey outliers, L and M; all parts of the cliff face therefore retreat about equally. The curved cliff face, G, is an arc whose center lies near the point, B, this point being the site of a re-entrant in the cliff face at that stage in its earlier history when its rate of retreat in the re-entrant was but little faster than that on the adjoining convex spurs A and C. The curves of these former convex spurs are likewise arcs whose centers are roughly indicated by the apices of the present sharp spurs, F and H, that now separate the amphitheaters. In other words, amphitheaters are forms into which the acutely re-entrant ravines of earlier stages systematically develop as the cycle of erosion progresses;

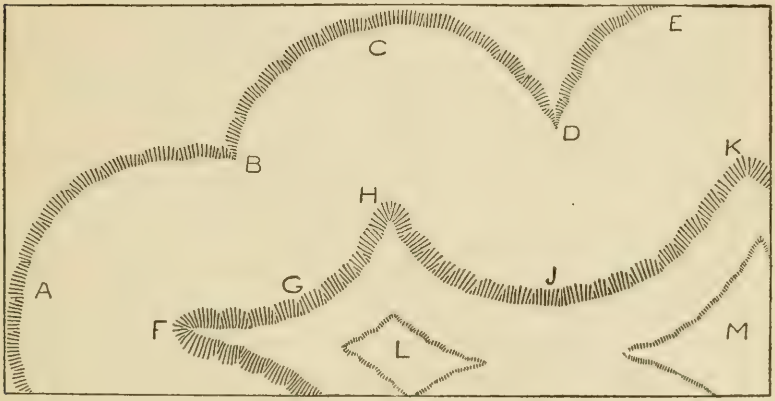

Figure 11.

Diagram of amphitheaters and cusps in the wall of the Colorado canyon.

similarly, the sharp cusps between the amphitheaters are the later stages of the round fronted spurs that once separated the ravines.

The Profile of Sharp Cusps. — When the red-wall spurs are sharpened into slender cusps all the overlying Aubrey strata are removed. The cusps are then unprotected by waste from above, and they are attacked on both sides by the weather. Under these conditions, the relatively even edge of the cliff in the amphitheater is exchanged for a serrated crest line, a true arête. Again when two amphitheaters head against each other, the isthmus of cliff wall between them is gradually narrowed and converted into an arête that sags in the middle. Arêtes in Alpine mountains occupy similar positions, but there the amphitheaters are usually cirques of glacial origin, as Richter and others have shown.

The strong color of the red-wall cliffs in the amphitheaters is due to staining by wash from the overlying lower Aubrey red beds. Where the serrated cusps stand forth, stripped of the Aubrey cover and out of the way of descending wash, the cliffs are gray.

It has been suggested to me by a correspondent, well versed in the topography of arid regions, that the amphitheaters of the canyon walls are more largely the product of wind action than would be inferred from the explanation here given for them. Certainly the wind is a powerful agent in regions where vegetation is as scanty as it is on the barren walls of the Colorado canyon, yet I cannot think that wind action is largely responsible for the amphitheaters, inasmuch as their slopes are always developed in accordance with lines of gravitative action and not in sympathy with the flowing lines characteristic of the bottom of an air current. The winds must often enough sweep the finer detritus about, yet its general disposition is essentially such as creeping and washing waste should assume. So with the regularly concave amphitheaters: under the control of wind action these forms might occur at various altitudes, irrespective of tributary slopes at higher levels. As a matter of fact, the concave amphitheaters are developed only in particular situations with respect to the wash of waste from higher levels, and therefore, however active the wind may be in shaping them, its activity must be subordinate to that of local weathering and of the down-slope movement of waste under the control of gravity.

General Relations of Amphitheaters and Cusps. – The correctness and generality of this view as to the origin of the amphitheaters and cusps are sustained by several lines of evidence. In the first place, the earlier forms, from which the cusps and amphitheaters of the red-wall in the Kaibab have been developed, are now imitated in the red-wall of the western part of the canyon in the Kanab plateau; here the progress in widening the canyon and in the accompanying sculpture of its walls has been relatively retarded by reason of the resistant nature of the whole Tonto formation, as has already been pointed out. The rim of the esplanade, which overlies and closely follows the pattern of the red-wall cliffs, repeatedly advances in great rounded promontories and recedes into sharply re-entrant ravines: amphitheaters and cusps of the Kaibab type are here unknown at the red-wall horizon. They are, however, already fairly well developed in the higher horizon of the resistant upper Aubrey beds, whose cliffs enclose the esplanade. The Aubrey cliffs, sapped by the weak lower Aubrey red beds, have here been worn back about as far from the axis of the canyon as the red-wall cliffs have been in the Kaibab; and the two are therefore in similar stages of development. As a rule, however, the Aubrey is traversed by too much drainage from the Kanab uplands for the development of perfect amphitheaters, although it shows sharp cusps at several points.

In the second place, the bench of Tonto sandstone in the Kaibab section exhibits rounded spurs and sharp ravine re-entrants where its dissection has been retarded in virtue of the resistance of the fundamental crystalline rocks that underlie the greater part of its extent; but on passing eastward beyond the apex of the "wedge," to the district where the Tonto is underlaid by the relatively weak Unkar series, dissection is much further advanced, and here the Tonto exhibits sharp spurs and concave amphitheaters that closely resemble those of the red-wall in the district already described; while the red-wall itself is reduced to slender buttes and pinnacles of small area, or altogether consumed. The various forms through which the cliff faces run are therefore evidently developed in systematic order.

In the third place, there is no need of a succession of resistant and weak strata for the production of the patterns outlined in Figure 11. All that is necessary is a mass that shall not possess horizontal diversity of structure by which the development of subsequent streams is guided in particular directions. Given a mass of horizontal or of homogeneous structure in which a drainage system with its branchwork of master and minor streams is in process of development: its contour lines must assume in due order all the patterns given in Figure 11. Not only so; the contour lines of the sculptured mass at mid-stage in the cycle have a certain historic value; those at lower levels exhibit the pattern from which the contours of the higher levels have been evolved; those at higher levels predict the pattern which many of the lower ones will in time attain. Some of the contours may gain an increased emphasis from following the outcrops of cliff-making strata; thus they catch the eye more readily than others which lie on evenly graded slopes; but all exemplify the same general principle. In the absence of strong cliff-makers, the high-level contours of spurs and isolated outliers will not assume the pattern of acute cusps; they will be rounded at their convex turns by the process of soil creeping, just as the crest-line divides are rounded; but in general the high-level contour lines in young or maturely dissected plateaus will show large re-entrant curves between relatively sharp salients (the sharpest salients or cusps occurring on contours that follow the outcrop of a cliff-making stratum), while the contours at low levels will show large salient curves between relatively sharp re-entrants (the sharpest re-entrants occurring on contours that follow a cascade-making stratum in an early stage of the cycle of erosion).

The Great Terraces.

Refreshed Cliff Profiles. — In my former report, it was stated regarding the great mesozoic escarpments or terraces, north of the canyon: "The sharpness of the cliffs is highly suggestive of aridity, but a relatively short arid period would suffice to sharpen the cliff profiles, even if they had been somewhat dulled by a previous humid period" (b, p. 188). This opinion needs a supplement concerning the change in the appearance of the escarpments that would accompany the transition from the subdued forms appropriate to a late stage of the plateau cycle, to the refreshed forms appropriate to the present young stage of the canyon cycle.

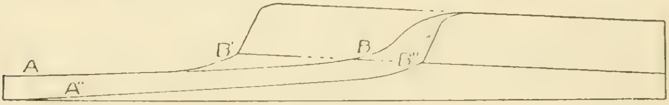

Figure 12.

The changing profiles of retreating escarpments.

In the later stages of a cycle of erosion in a region of nearly horizontal structure many escarpments may have retreated far back from the main waterways. The graded floor of the peneplain of degradation, A B, Figure 12, may then ascend gently to such an altitude at the base of the escarpment, B, as to stand there above the level of the weak strata which underlies the strong escarpment maker. Under such conditions, the future retreat of the escarpment will be relatively slow, and its aged form must therefore be less abrupt than at an earlier stage of the cycle when the graded floor, A B′, rose only midway in the mass of the weak strata; for at this earlier stage, the retreat of the escarpment must have been accelerated by the sapping of its base, and it must then in its vigorous maturity have had a bold and constantly refreshed face.

Now if the aged region enters a new cycle of erosion, in consequence of broad uplift, the main river quickly erodes a canyon and already in the youth of the new order of things will be found at a significant depth beneath its former channel. In due time, the side streams will entrench themselves beneath the peneplain of the former cycle; a new graded floor A″ B″ will be opened with respect to the streams, and the subdued cliff will be actively attacked as the weak strata beneath the cliff-maker are worn away; the cliff will thus be again steepened or refreshed.

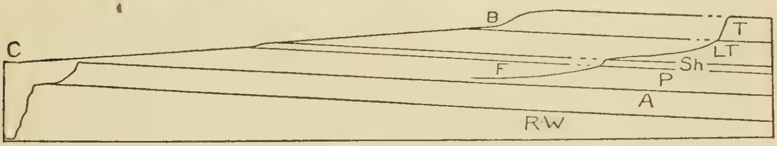

Figure 13.

Generalized section of the plateau from the Colorado canyon to the Vermilion cliffs near Pipe spring. Abbreviations: — R. W., Redwall limestones; A, Aubrey group; P, Permian; Sh, Shinarump sandstone; L T, Lower Trias clays; T, Triassic sandstones.

Inasmuch as the Colorado canyon is to be explained as the result of a new attack of erosive forces on an uplifted peneplain, there seems to be equally good reason for explaining also the bold cliffs in which the strong Mesozoic strata outcrop north of the canyon as the result of a revival of erosive forces on the subdued cliffs that once bordered the peneplain. It is not possible at present to determine the amount of retreat that the cliffs have suffered in the renewed attack made upon them in the canyon cycle; but in the case of the Vermilion cliffs at Pipe spring the retreat is likely, it seems to me, to have been several miles at least. The reason for assigning so considerable a measure to the retreat of these cliffs is found in the probability already stated that a large volume of weak Permian and lower Triassic strata have been worn off of the plateau in front of the cliffs during the canyon cycle. At the beginning of that cycle, when the Colorado river, C, Figure 13, flowed at or above the level of the upper Aubrey limestones, a gentle sloping surface, C B, over Permian and lower Triassic strata, in which the Shinarump cliff must have been nearly extinguished, is inferred to have extended from the river plain northward to the base of the faded Vermilion cliffs.

To-day, the plateau in the neighborhood of Fredonia and Pipe spring is a thousand feet lower than it is at the rim of the canyon. It is true that some of this difference of level may be attributed to an inequality in the uplift by which the canyon cycle was initiated; but the great altitude of the High plateaus further north does not encourage the supposition of less uplift there than in the south. It seems more probable that the lower surface by Fredonia and Pipe spring is due to the extensive erosion, during the early stages of the canyon cycle thus far elapsed, of a large body of weak strata, whose persistence to the close of the plateau cycle was due to their lying below the level at which streams could then attack them, and whose early removal in the current cycle is due to their being raised high above the level of active stream work. It should be remembered in this connection that good warrant for the abundant erosion of Permian clays during the canyon cycle has been found in the study of the Hurricane fault in the Trumbull district. Accompanying the removal of the weak strata in the Pipe spring district, there must have been a resurrection of the nearly extinguished Shinarump cliffs, Sh, and a refreshment of the subdued Vermilion cliffs, T. These bold forms, presenting to-day every indication of rapid retreat, are therefore to be associated with the Grand canyon as the work of very modern erosion on pre-existent forms of much weaker relief. How general this change may be I cannot say, but it may well include all the Shinarump escarpments in whose under slope the Permian clays are laid bare in sharp-cut ravines as in Plate 3 B, and all the ragged Triassic escarpments along which landslides have occurred as stated in my earlier essay (b, p. 121) in consequence of the recent removal of the weak lower Triassic clays: views of such escarpment are given in Plates 2 B, 6 A, and 7 A.

Revived Erosion of the Pink Cliffs. — The Pink cliffs of the Paunsagunt plateau did not fulfil the expectation that had been awakened by Powell's and Dutton's descriptions of them, probably because the southwestern border of the plateau that we saw is less precipitous than that on the southeast (Dutton, a, p. 254). In the thirty miles or more of the escarpment that we followed, it is only intermittently bare and pink; much of the front has a graded slope, green with forest trees. Cliffs of bare and precipitous rock occupy only about half the length of the escarpment, as it is seen from the lava-capped hill where the Panguitch-Kanab road crosses the divide between Virgin river and Kanab creek; and all these cliff faces are evidently the result of a revival of erosion in the Kanab headwaters by which the tree-covered slope, formerly continuous, has been locally attacked and worn away. The once subdued escarpment has thus been here and there eroded back into cliff-walled amphitheatral recesses, whose pink faces are seen between the forest-covered slopes that still record an earlier stage of erosion.

The revival of stream erosion by which the Pink cliffs are thus locally refreshed may be associated with the revival of degradation by which the present graded floor of Upper Kanab creek has been lowered beneath the level of earlier grades, whose remnants may be clearly seen stretching southwestward beneath the outermost point of Paunsagunt plateau. Both these consequences of revival may be plausibly associated with the elevation of the region by which the canyon cycle was introduced; and the relatively small amount of work here accomplished in the new cycle as compared to the much greater work accomplished in the same period of time by the Colorado, the trunk river of the region, may be reasonably ascribed to the normal delay of small headwater streams in taking cognizance of uplifts, as compared to the promptness with which advantage is taken of such opportunities by the main rivers.

The upland of the Paunsagunt plateau is drained by the consequent northeast-flowing headwaters of the East fork of the Sevier. When the upland was first formed, the streams must have headed decidedly farther south than they do now; for they have been significantly shortened by the recession that the Pink cliffs have suffered during the excavation of Upper Kanab valley. The indentations in the scalloped sky line of the cliffs mark the present heads of these shortened streams.

THE VALLEY OF THE VIRGIN. — The towers and temples of the Virgin canyon in the Triassic terrace of the High plateaus have been described in glowing language by Dutton (b, Chap. III.). As in the Colorado canyon, the cross-section of the Virgin canyon exhibits a perfect response of form to structure, and an absence of benches independent of structure such as would be expected had there been a significant pause during the elevation in consequence of which the canyon has been eroded. At Rockville, a few miles below the junction of the North and East forks of the Virgin, the river flows in the middle Permian clays;

here the Shinarump sandstone forms a strong bench, back from which the huge upper Trias cliffs, Plates 6 A, 7 A, have retreated from two to four miles, in consequence of active sapping by the underlying weak lower Trias clays. The general profile is shown in ABCDE, Figure 14. In following up the North fork, the valley or canyon becomes narrower until it is hardly more than a cleft: this is the remarkable Mukuntuweap canyon of which Gilbert gave an account thirty years ago (p. 79) and of which we saw the entrance last summer; our own failure to enter it being due only to that oft-prevailing difficulty in geological excursions, a lack of time. The cleft has been given fame from the reproduction of Gilbert's figure of it on the back cover of Leconte's Elements of Geology, where it has often been mistaken for a section of the Colorado canyon. The open lower canyon of the Virgin here narrows to an enclosed cleft because the gentle northward dip of the strata combines with the northward ascent of the river bed to raise the stream from a mid-Permian to a mid-Trias horizon; here it finds only the heavy and resistant sandstone cliff-maker, B, almost free from partings on stratification surfaces, but well provided with vertical joints; as a result, the rocks at the canyon bottom exert no sapping action on those higher up the walls. The cross-section of the canyon at any intermediate point between Rockville and the cleft may be represented by imagining a vertical line at an appropriate position, as F, on the profile ABCDE, and reproducing the upper part of the profile, ABCF, on the right of the vertical, as A′B′C′F.

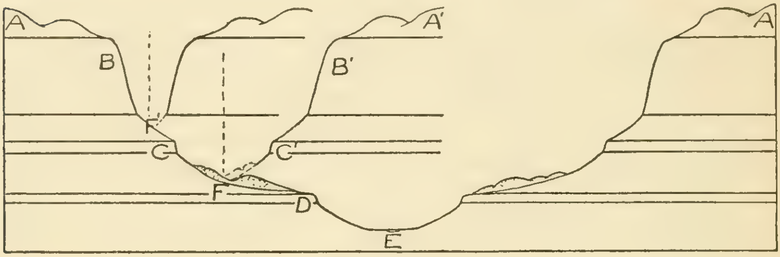

FIGURE 14.

Generalized cross-section of the canyon of Virgin river.

It is only at higher levels than those exposed in the deeper part of the Virgin canyon that traces are found of an older topography, formed in an earlier cycle of erosion than that in which the canyon as a whole was eroded. Some account of the older topography will be given in the Bulletin by Messrs. Huntington and Goldthwait to be issued.

The huge landslides along the base of Echo and Vermilion cliffs east of the Kaibab were ascribed, in my previous essay, to an active sapping of the weak Triassic clays under the cliffs in consequence of the revival of erosive processes that followed the uplift of the Canyon cycle. Numerous landslides of similar stratigraphic position were observed during the past summer in the valley of the Virgin near Rockville. They are extensive and abundant, and large enough to appear in Plates 6 A and 7 A. It is a matter of surprise that they are not mentioned in Dutton's account of this district. Where the valley is broad, the slides lie for the most part on the Shinarump bench, as in Figure 14: they have the form of disorderly mounds and hills, from two hundred to six hundred feet high, strewn with huge boulders for which there is no local source in the form of immediately surmounting cliffs; indeed, some of the mounds stand one or two miles forward of the Triassic cliffs from which they were derived. One example was noted in which the front of a slide descended below the Shinarump cliff into a ravine worn in the Permian slopes beneath; and this slide has been utilized for the construction of the roadway from Canaan spring to Rockville, the Shinarump cliff being apparently impassable elsewhere for several miles up and down the valley. There appears to have been a significant amount of erosion since the slides took place, for their slopes seemed to be of greater uniformity than would likely have been the case in their initial disorder.

As one passes up the valley of the North fork, the Shinarump bench, Plate 7 A, gradually decreases in height and soon disappears under the valley floor. The landslides then advance directly toward the stream, and five miles further north they form a serious barrier in its course: here for a mile or more the channel is interrupted by bouldery rapids. The landslides then cease, because the weak clays by whose sapping they were caused have run under ground, and the valley floor has a flat flood-plain for two miles or more, apparently the result of alluvial filling caused by the landslides barrier below. The flood-plain is known as Zion; it is cultivated by the farmers who come up the rough road over the landslides from the villages down the valley. A mile further on, the stream bed rises above the shaly sandstones that elsewhere form a slope beneath the heavy upper Trias cliff-maker, and here the cliffs close in precipitously upon the stream, producing the cleft-like Mukuntuweap canyon, already mentioned. The rock walls of Zion, Plate 6 B, are of wonderfully massive structure, steep, bare, and clean: they frequently show cross-bedding, but the texture of the sands is so uniform that there is little or no weathering along the bedding planes. The cliffs retreat by the detachment of huge slabs on vertical joint planes, but the amount of talus seems very small in proportion to the great height of the cliffs. Hanging lateral valleys open at various heights in the main valley walls; and above the level of the higher lateral valleys the cliffs rise in rounded domes, which seem to record a more mature stage of erosion during an earlier cycle, when the land stood lower than at present.

The rolling plateau country in which the canyon is incised was described to us as affording abundant pasture and timber. A zigzag path has recently been constructed on one of the more battered parts of the canyon wall: part of the path consists of tree-trunks held against the rock face by iron clamps and brackets. Cattle are here driven up to the highlands for summer pasture. A wire rope has lately been stretched from a bold cliff-top down into the valley, to serve for lowering boards and shingles from the upper forest. The height of the cliffs is so much greater than can be properly estimated that I refrain from indicating it in feet; but the rough units of measure should be thousands rather than hundreds.

The Fresh-water Tertiaries.

Previous Statements. — During the past summer I had opportunity of examining with some care several characteristic sections of the fresh-water Tertiary formations which occupy so large an area in the Cordilleran region. The localities to be described here are those of the Eocene beds exposed in the Pink cliffs of the Paunsagunt plateau and thereabouts in southern Utah, and the Green river beds near the town of that name in Wyoming. The object of this study was to consider on the ground whether the theory of the unqualifiedly lacustrine origin of these formations, presented in the various reports on the geology of the region, would command entire acceptance. The lacustrine theory has been, until recently, practically undisputed for thirty or more years, but a number of essays have now been published in which the capacity of aggrading rivers and of winds to form extensive non-marine deposits has been recognized, and in which the effort has been made to discriminate carefully between fresh-water formations of different origins. In a number of these essays, especially in those by Matthews, Hatcher, Johnson, Merriam, and Calkins, the lacustrine theory has been definitely replaced by theories of fluviatile or æolian agencies, and at present there is evidently a strong tide of opinion turning from the unqualifiedly lacustrine origin of the various fresh-water Tertiaries; but in just what manner the unqualified lacustrine theory shall be amended or replaced is not yet apparent in all cases. Indeed, this aspect of the problem can be settled only by extended and detailed study in the field of each formation. It is essential in the prosecution of such study that a critical attention should be given to the deposits now accumulating in and around the basins of large and small, deep and shallow lakes, as well as on the flood-plains of large and small rivers; for at present one of the chief difficulties of the problem comes from a lack of knowledge regarding the characteristic minute structures of such deposits. Truly the day is passing when coarse conglomerates and cross-bedded sandstones can be described as of lacustrine origin without leaving some doubt in the mind of the geologist who reads so undiscriminating a description; but the day has not yet come when even-bedded, fine-textured strata are habitually and critically examined to learn whether they are of lake-bottom or of flood-plain origin.

It is confidently believed that one of the best aids towards the solution of the class of problems here considered that an observer can carry with him into the field is a careful analysis of the many possible conditions under which continental deposits may accumulate. It is in particular important to recognize on the one hand the very fine and uniform deposits that should characterize the central area, and the coarse deposits that should accumulate around the marginal area of long-enduring lakes of large area and considerable depth, with their shores close against the base of encircling mountains; and on the other hand the very variable deposits that should characterize short-lived, fluctuating lakes of small area and slight depth, with ill-defined shores on gently sloping fluviatile plains of piedmont waste. With such an analysis in mind, the observer is likely to find it difficult to reconcile the theoretical conditions suggested by such phrases as a "lake of vast dimensions" and "the great Eocene lake" with the variable deposits that prevail in many of the Tertiary basins.

EOCENE OF THE HIGH PLATEAUS OF UTAH. — Our route to the head of Sevier river, south of Panguitch, and thence over the low divides to the headwaters of the Virgin river and of Upper Kanab creek and to the Pink cliffs of the Paunsagunt, led us past many excellent exposures of the Eocene, described by Howell and Dutton. The refreshed faces of the

Pink cliffs exhibit an unusually fine section from the brown shales and sandstones that we took to be upper Cretaceous up to the pink-stained white limestones of the Eocene. The Cretaceous, outcropping abundantly on the sides of the valley by which the cliffs were approached from Upper Kanab, consists of brown and gray muddy sandstones and shales, abundantly cross-bedded. How far this formation should be classed as marine because some of its beds contain Ostreas, or continental because other beds include coal seams, remains to be determined. The uppermost brown beds, in the slope under the cliffs, are overlaid by about fifty feet of fine-grained reddish beds ; "reddish mud" suggests their original condition. These are separated from the next higher members of the series by a gently undulating surface of unconformity. Then come about twenty feet of fine cross-bedded sandstone, followed by more evenly bedded strata which seemed to merge upwards into a fine, evenly bedded or massive white sandy limestone, whose cliff face is stained a more or less vivid pink where the drainage from the upland washes over it, but which has a creamy white color in the more isolated promontories and pinnacles. The lacustrine origin of these beds, which contain fresh-water mollusks according to Howell (p. 267–274), does not seem open to question so far as the limestones are concerned, but several purplish partings, a few feet thick, occur within the limestone series, and this variation of the beds does not seem consistent with the theory of their deposition in a vast lake. The partings are not continuous, but are seen to thin and end as they are traced a few hundred feet along the embayment in the cliff face that we visited. Howell said of the formation in general : "These Tertiary beds are so extremely variable in lithological character and thickness, that it is difficult to correlate sections, even when taken only a few miles apart, save in a very general way. This is especially noticeable in comparing sections near the western boundary of the system . . . while the eastern sections show more uniformity" . . . (p. 266).

The strata exposed in the hills near and at the divide between the Sevier and the Virgin are higher in the series than those in the Pink cliffs. Here we saw impure whitish or creamy limestones, sometimes evenly bedded, sometimes with wrinkled layers (as if locally disturbed by change of volume between unchanged under and overlying layers), sometimes without apparent stratification ; but the limestones are associated with cross-bedded sandstones, both below and above, and with occasional reddish beds. The cross-bedding of the sandstones occurred in layers usually less than a foot in thickness, and showed rapid variations in distances of four or five feet. Well-defined outcrops of these sandstones, five or ten feet thick, weakened and disappeared when followed for a few hundred feet along a hillside. This was especially well seen on a slope just north of the Sevier-Virgin divide, where it could be explained only by the thinning out of the sandstone itself. On the divide and over some of the hills near it, we found the residual pebbles of a conglomerate that might probably have been discovered in place in localities where somewhat higher strata still remained intact.

Whatever share may have been taken by lakes in providing a site for these various deposits, it seems evident that the persistent existence of a single, large, continuous water body does not supply the conditions necessary for the accumulation of strata in which variations of composition, texture, and structure are so common.

THE GREEN RIVER BASIN, WYOMING. — The following notes on this interesting district are based on two half-day walks over the hills north and east of Green River station, Wyoming, supplemented by observations on natural outcrops and railroad cuts from passing trains.

The "paper shales" at Green river have often been instanced as proving the lacustrine origin of the formation of which they constitute so large a part, and it was with the special object of examining them closely that I made a short stop at this point on the Union Pacific railroad. The cut where most of the fossil fish have been found is now, I was told, filled in the new grading of the railroad, but many excellent sections of the formation are exposed in the dry ravines that dissect the barren slopes of the uplands through which Green river has here opened its valley. The outcrops are especially clear on the slopes towards which the river has lately swung, thus causing an entrenchment of the lateral watercourses and a stripping of the loose waste that tends to accumulate on those slopes from which the river has moved away. The best example of this kind that I visited was from a quarter to a half mile southeast of the point where the railroad leaves the river to turn eastward up the valley of Bitter creek, a mile or more east of the station. The lowest beds here seen are whitish shales with some partings of fine sandstones, about one hundred feet in total thickness. These are capped by a stronger sandstone, dull greenish brown in color, commonly showing cross-bedding, and varying in thickness up to about fifteen feet. The outcrops of this sandstone on both sides of Bitter creek valley determine a more or less continuous bench. As the strata here dip gently westward, the sandstone disappears underground a little west of the mouth of Bitter creek, so that it outcrops only near the base of the bluff northeast of the town. In the abundant outcrops south of Bitter creek it was seen to be made up of lenticular deposits, whose groups of oblique beds rapidly vary in thickness. Neighboring sandy strata frequently exhibit a lenticular and cross-bedded structure on a small scale, in strong contrast to the even-bedded deposits of the paper shales, or cardboard shales as I should prefer to call them. In one exposure, a layer of sandy shale four feet thick has been obliquely cut out in a distance of eighteen feet, and the excavated space was filled in with innumerable little lenses and cross-beds. In another exposure, a series of somewhat concretionary, somewhat lenticular beds is cut out to a depth of two feet in a length of five, and the cavity is filled with rather even layers, followed by finely lenticular beds; the surface of local unconformity has in this latter instance a maximum dip of 30°. For a hundred feet or more over the sandstone bench, there are frequent alternations of gray cardboard shales with whitish calcareous and gray sandy layers, whose wasting outcrops supply the slopes with abundant slabs, large and small. The shales are of a remarkably even and continuous stratification, for which a lacustrine origin seems eminently appropriate, and a fluviatile origin on a broad flood-plain hardly less so; but the frequent alternations of the shales with layers of other kinds indicate equally frequent variations in the form or depth of the parent water-body, whatever it was. Some of the varying beds are greenish marls, with no distinct stratification in layers three or four feet thick. The sandstones are gray while in place, but weather brown as they creep down hill: some of the slabs show regular ripplemark, with crests from two to four inches apart; others are unevenly rippled and pitted; many of the layers show fine cross-bedding; a few contain rounded fragments of shale. Various samples are shown in Plate 7 B. Some of the calcareous beds have their layers separated by thin and variable clay partings which thicken up to a quarter or half inch, and then thin out in eight or ten inches. Other calcareous layers are seen, when weathered, to consist chiefly of fine pebbles well cemented, though this structure might not be suspected from a surface of fresh fracture: the constituent pebbles and grains, up to quarter or half an inch in diameter, are usually well rounded; they are often soft and clayey. The best specimens of this kind were found in the bluff northeast of the town. Their resemblance to certain specimens of tepetate, brought by Mr. R. T. Hill from the arid southwest, is very striking. The continuity of stratification in these variable deposits is noteworthy. Bands of lighter and darker color may be traced for several miles on the northern slopes of Bitter creek valley. On the other hand, there must be frequent minor lapses of continuity, for the thin sandstone beds are certainly more common on some slopes than on others not far away at the same horizon. It should be noted in this connection that no one yet has carefully determined the degree of continuity that may prevail in the deposits of overflowing aggrading rivers.

The higher members of the shales and the whitish calcareous beds show fewer variations of structure than those beneath. They are succeeded by fifty feet or more of inconstant deposits that vary from paper shales to cross-bedded sandstones, increasingly changeable in composition, texture, thickness, and color. Some of these upper sandstone beds wedge out from five feet to nothing in a distance of fifty feet. Then come the capping bluffs of variable brown sandstone from forty to sixty feet or more in thickness, frequently of even texture and massive beds; again showing pronounced cross-bedding on a large scale. In the well-known butte that forms so conspicuous a landmark north of the town, there are local deposits of a bluish clay, twenty feet or more in length, yet hardly an inch in thickness, contained in the sandstone. In spite of the strength frequently attained by these capping beds, and in spite of the bold face which their outcrops often possess, the bluffs which the outcrops form are by no means continuous. They occur chiefly in promontories and on isolated buttes, along the margin of the less dissected upland that here borders the valleys of Green river and its larger branches. The re-entrants between the promontories are frequently of evenly graded slope without any strong capping sandstone bluff. In other districts of the west, the continuity of a rimming bluff formed by a hard horizontal layer as it contours around spurs and into ravines is of common occurrence, and for that reason the discontinuity of the bluffs around Green river very strongly suggests the discontinuity or at least the great variability of the bluff-making sandstones. Thus interpreted, the bluffs of the promontories and isolated outliers must mark local thickenings of the sandstone in the mass of weaker shales. It seems evident that if the cardboard shales are accepted as the deposits of a lake, the variable bench — and bluff — making sandstones must be of some other origin.

Bridger and Vermilion Creek Tertiaries. — The Union Pacific railroad between Green river and Weber canyon crosses broad areas of the Bridger and Vermilion creek formations. Natural outcrops are abundant for much of the way, and many artificial exposures are seen in the cuts along the track. Observation from an express train cannot be detailed, but it suffices to prove that the strata of these formations often depart very far from the fine-grained, even, and thin-bedded deposits that are appealed to in the Green river formation as convincing evidence of lacustrine origin. In the Bridger area, there are abundant alternations of shales and sandstones; in the Vermilion creek area, of sandstones and conglomerates. Many of the beds are visibly lenticular and local, implying rapid variations in the conditions of origin, horizontally as well as vertically. But there is little new in all this, so far as facts of structure are concerned. Many details of structure are accurately stated in the reports of the Fortieth Parallel Survey. For the Bridger formation, we read : along the line of the railroad the lower members of the formation are seen "consisting of thin-bedded drab and greenish sandstones and clays" (ii. 245). North of Echo canyon, the Tertiaries consist "chiefly of red sandstones containing some fine shale and clay beds, and limited sheets of conglomerate" (ii. 331). It is chiefly to the interpretation rather than to the record of the facts that renewed analytical discussion should be directed.

It was perhaps natural at the time that the early western surveys were undertaken to class all fresh-water basin deposits as lacustrine; but the thirty years that have elapsed since then have as naturally introduced new interpretations. The unanalyzed, undetailed theory of wholesale deposition in a series of great lakes now seems to be entirely untenable for many of the fresh-water Tertiary formations of the Rocky Mountain region. The fine calcareous shales of the Green river formation strongly suggest deposition in standing water; but the associated cross-bedded sandstones imply an activity of movement in the depositing agent such as would characterize a stream rather than a lake. The heavy, coarse, and variable conglomerates of the Vermilion creek formation suggest deposition by running water; there seems to be no local indication of lacustrine conditions. The real need here is a resurvey of these formations, in which the facts shall be interpreted in view of all possible conditions of deposition.

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EXPLANATION OF PLATES.

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1 A. An outlier of the White cliffs; Jurassic sandstone next west of Kanab creek.

1 B. Detail of the base of Plate **1**, showing cross-bedding.

2 A. Detail of cross-bedding in Jurassic sandstones, west branch of Kanab creek.

2 B. Vermilion cliffs: Triassic sandstones west of Pipe spring.

3 A. Sevier Fault at Pipe spring: looking north. In middle distance, the Shinarump bench, coming from the east, is cut off by the fault. The Triassic cliffs follow in the background. On the left, the Triassic cliffs stand in the middle distance beyond Moccasin valley.

3 B. Shinarump mesa with Permian slopes, between Antelope wash and Canaan gap.

4 A, B. The south wall of the Colorado canyon from the northern esplanade east of the Toroweap fault. The two views overlap slightly. Two ash cones lie on the esplanade in Plate **4** B.

5 A. South Toroweap valley, from the southwestern corner of the northern esplanade. The uplifted esplanade sandstone at the left margin is the same stratum as that of the general level of the valley floor. The cliffs in the central foreground are capped with lava: a small ash cone lies on their edge to the right.

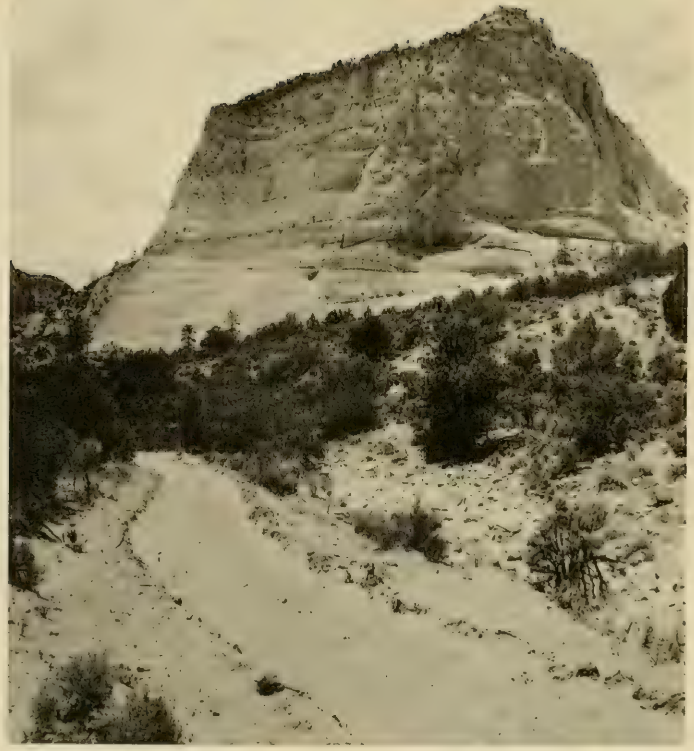
5 B. Looking down the Colorado canyon from Vulcan's throne. Lava sheets form the slopes on the right. The Shivwits plateau is seen in the distance.

6 A. The "West Temple": Triassic cliffs over the Shinarump bench, valley of the Virgin at Rockville. Landslide masses at base of the cliffs.

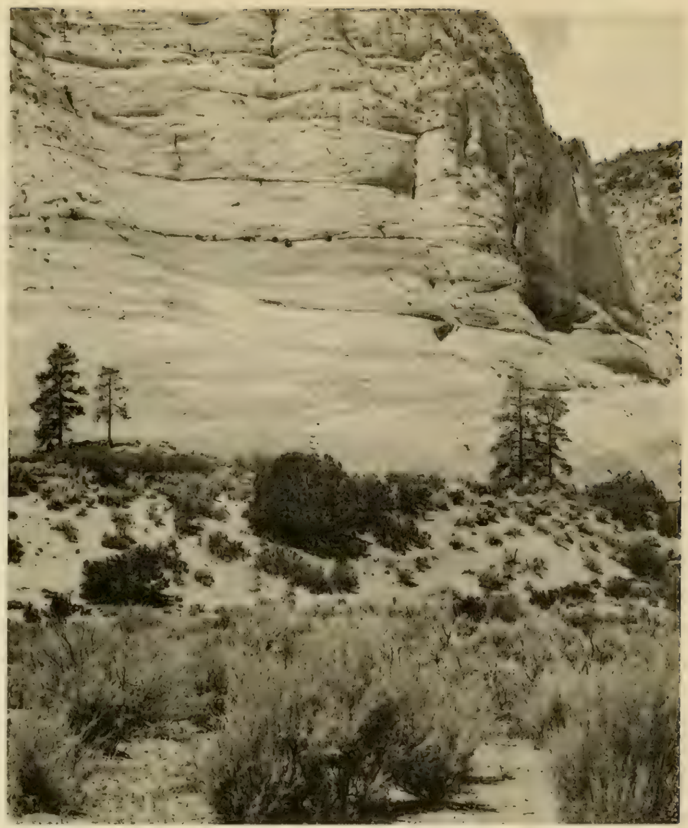
6 B. The Cliffs of Zion, Mukuntuweap canyon; Jurassic and Triassic sandstones.

7 A. Looking southeast across the valley of the Virgin at Rockville from the Shinarump bench. Many of the hills on the Shinarump bench on the further side of the valley are landslides that have run forward from the Triassic cliffs in the background.

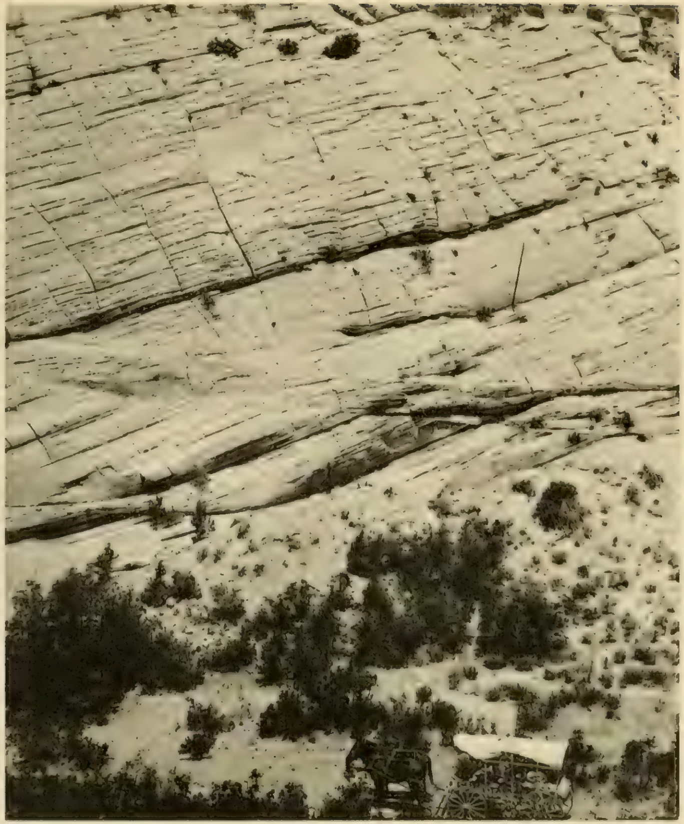
7 B. Slabs of sandstone from the Green river Tertiaries, Wyoming.



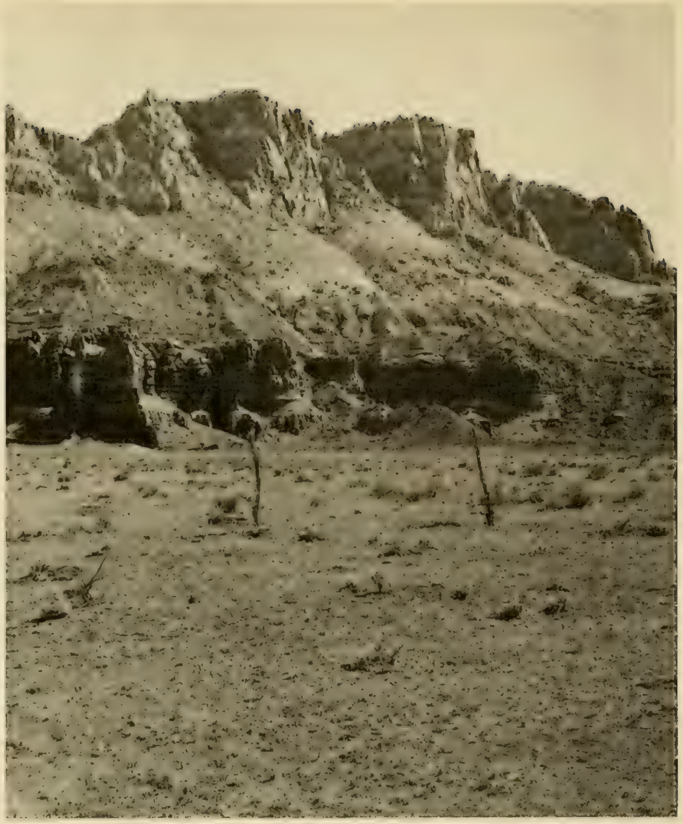
A. AN OUTLIER OF THE WHITE CLIFFS.



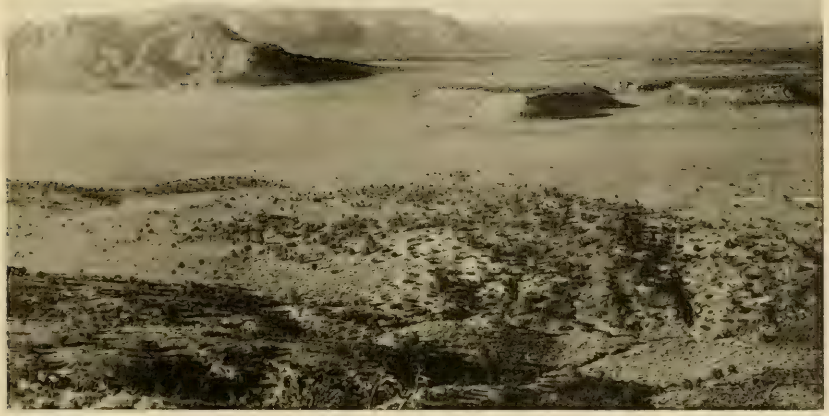
B. CROSS BEDDING IN THE WHITE CLIFFS.



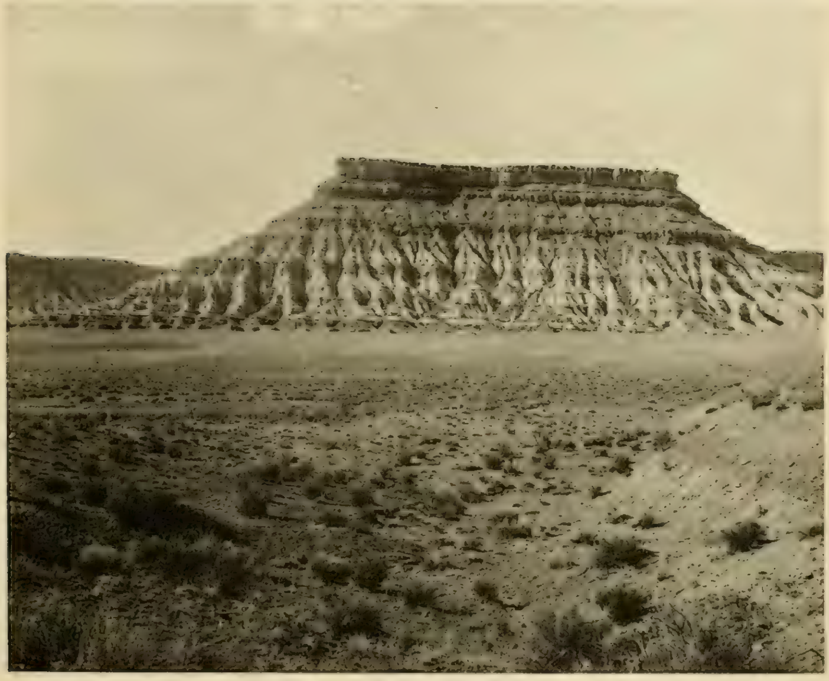
A. CROSS BEDDING IN THE WHITE CLIFFS.



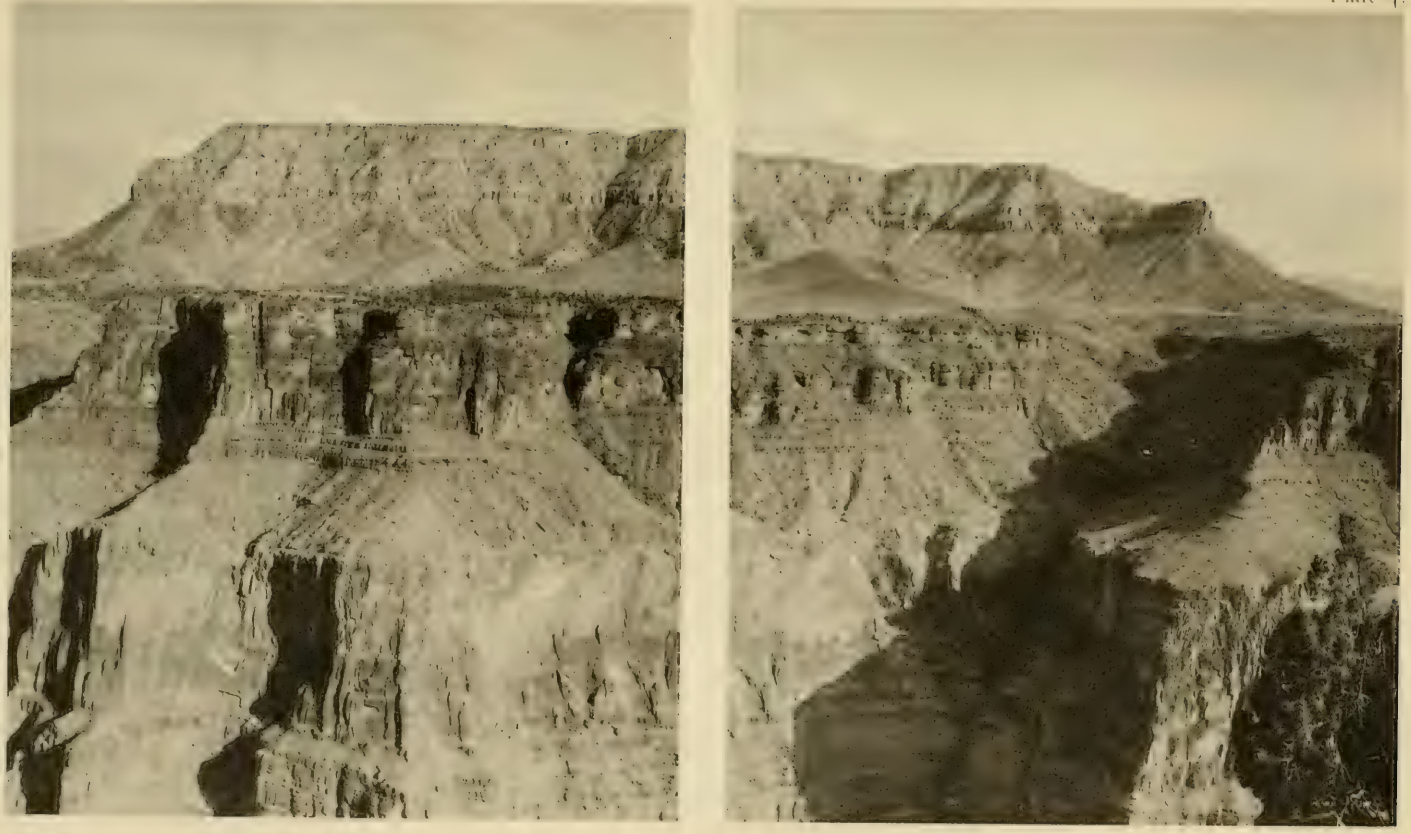
B. VERMILION CLIFFS NEAR PIPE SPRING.



A. THE SEVIER FAULT NEAR PIPE SPRING.

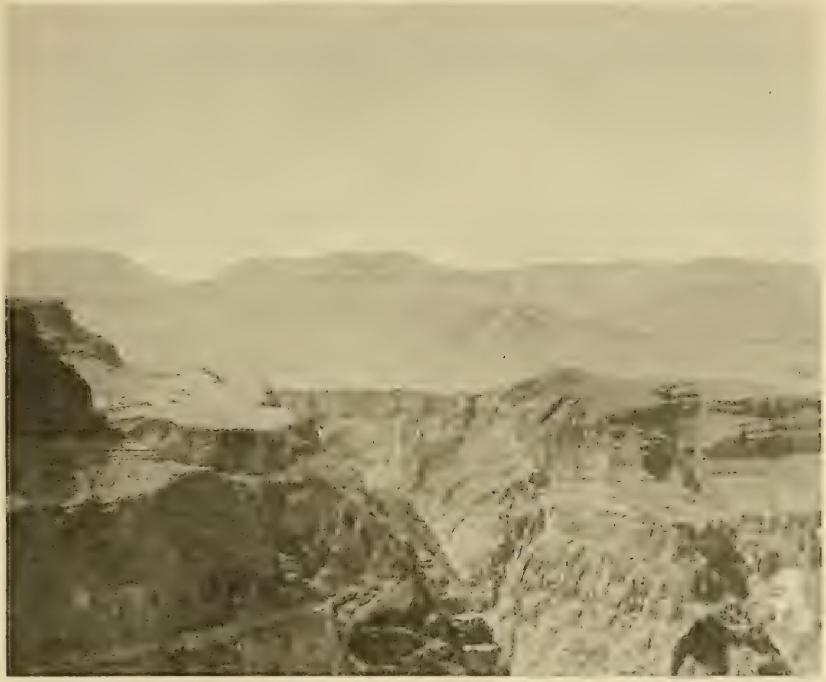


B. A MESA OF SHINARUMP SANDSTONES ON PERMIAN CLAYS.

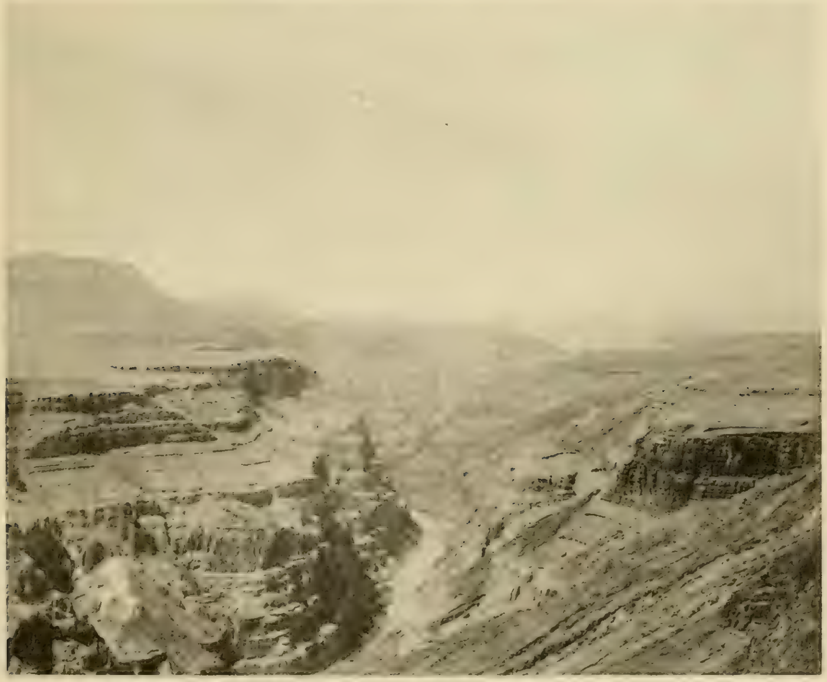


A. B.

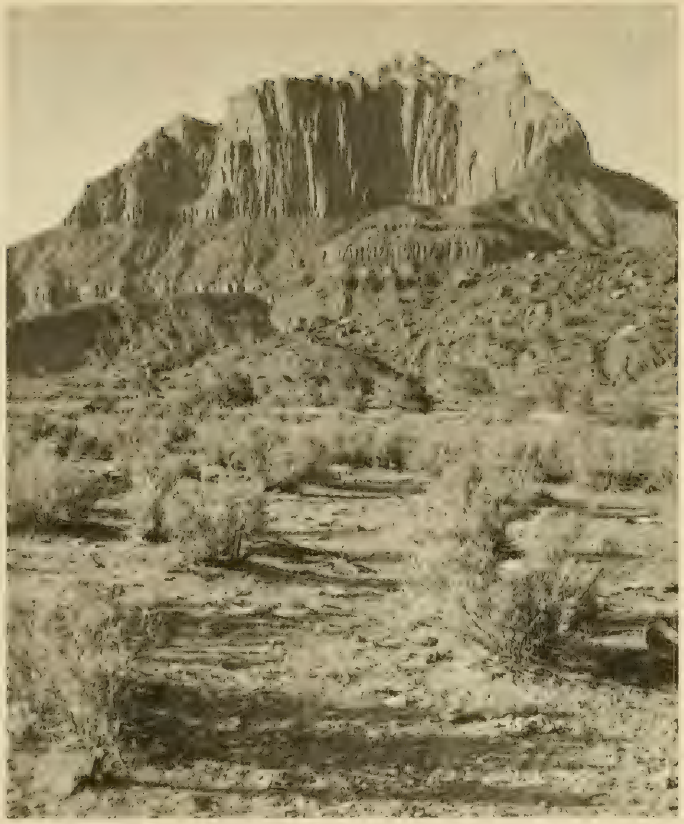
SOUTH WALL OF THE COLORADO CANYON.



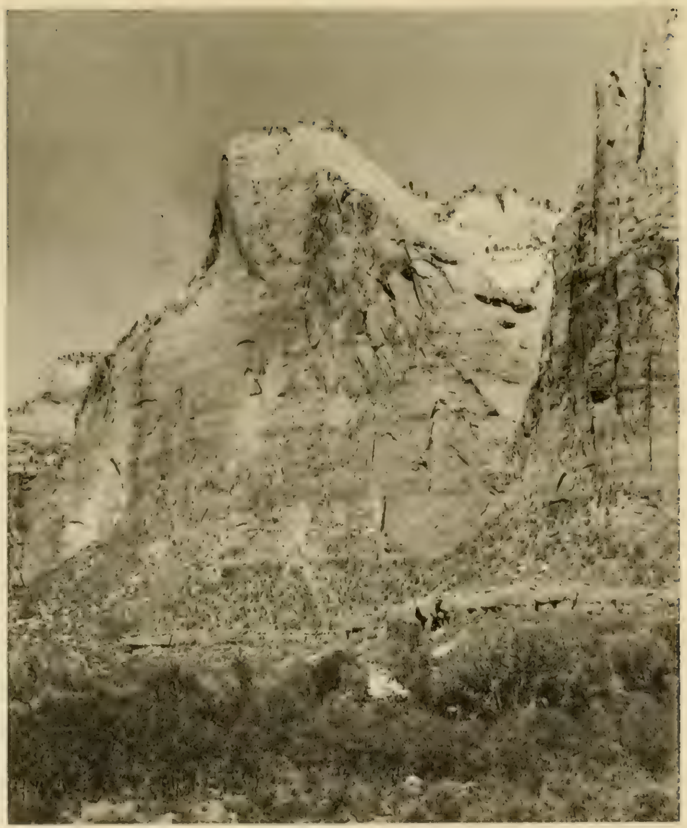
A. SOUTH TOROWEAP VALLEY.



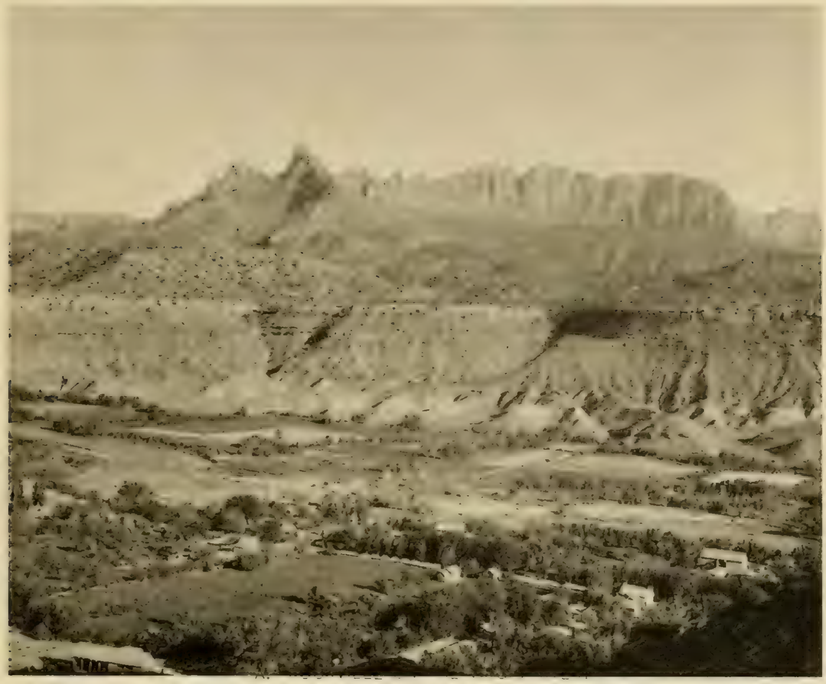
B. DOWN THE COLORADO CANYON FROM VULCAN'S THRONE.

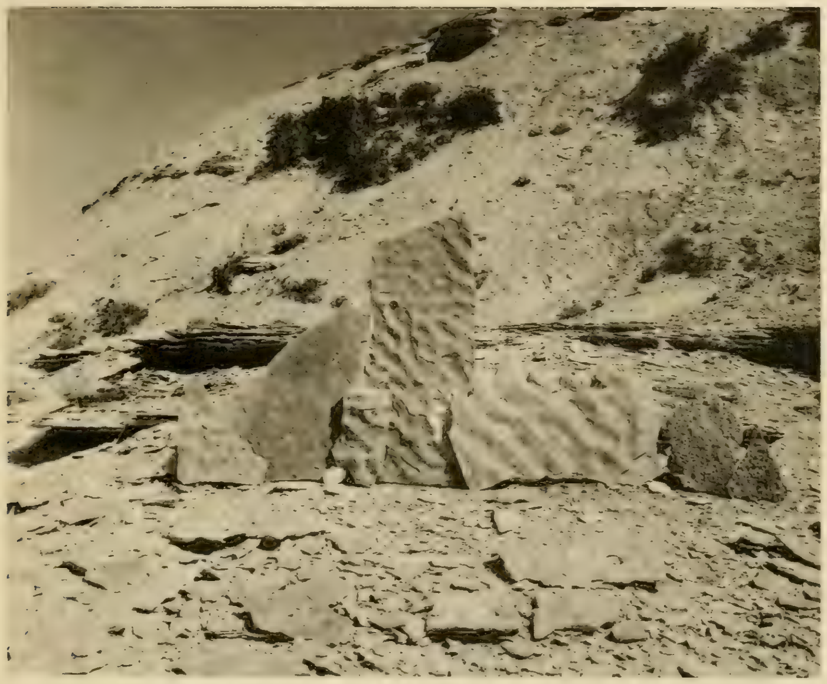


A. WEST TEMPLE, VALLEY OF THE VIRGIN.



B. CLIFFS OF ZION.





B. RIPPLED SANDSTONES IN THE GREEN RIVER FORMATION.

Bulletin of the Museum of Comparative Zoölogy
AT HARVARD COLLEGE.
Vol. XLII.

GEOLOGICAL SERIES, Vol. VI. No. 2.

THE CHEMICAL COMPOSITION OF LIMESTONES FROM UPRAISED CORAL ISLANDS, WITH NOTES ON THEIR MICROSCOPICAL STRUCTURES.

By Ernest W. Skeats.

CAMBRIDGE, MASS., U.S.A.:
PRINTED FOR THE MUSEUM.
June, 1903.

No. 2. — *The Chemical Composition of Limestones from Upraised Coral Islands, with Notes on their Microscopical Structures.*[1]

By Ernest W. Skeats.

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I. Introductory.

Since Darwin's historic voyage in the "Beagle" nearly seventy years ago, and Prof. J. D. Dana's work in connection with the United States Exploring Expedition (Wilkes) of 1838–42, perhaps no two subjects of geological interest have excited more attention and aroused more discussion than the question as to the origin of coral reefs and the problem of the formation of dolomite.

The work of subsequent investigators, especially that of Sir John Murray, in connection with the Challenger Expedition, has considerably increased our knowledge of the conditions under which coral reefs may be formed.

Within the last five years interest in this subject has been still further stimulated by several expeditions to localities in the Pacific and Indian oceans, which have been made with the object of extending our information as to the structure and origin of coral islands and to throw light on other problems related to this important question.

The expeditions to the Funafuti Atoll (1897–99) under Professor Sollas, and later under Prof. Edgeworth David, were organized by a Committee of the Royal Society, acting in conjunction with the Geographical Society of New South Wales. A boring was made through the rim of the atoll and this eventually reached a depth of 1114 feet.

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[1] Reprinted with additions from the copy privately issued in 1902.

The results of the inquiry are not yet published, but there is no doubt that they will be found to be of great interest and importance, both in connection with the question of the origin of coral reefs and also in their bearing on the formation of dolomite.

Methods of collecting Specimens. — In the Funafuti Expedition a boring was made on the edge of the reef, and a vertical succession of specimens was thus obtained. In that case, if the boring was in solid reef throughout, the position of a particular specimen determined its age relatively to those above and below it. This method of collecting has the further advantage that where a gradual structural or mineralogical change occurs in the rock, the change can be closely followed by specimens at short intervals, but its great cost renders it of only limited application. In the case of collections from raised coral reefs much the same result was sought by collecting in vertical sequence from cliff faces, ravines, etc., at heights definitely ascertained by measurement or by the records of the aneroid barometer.

During the upheaval of a coral island accretions to the older rocks occur, to a greater or less extent, in the form of fringing reefs, several of which are often found at successive heights on one island, marking pauses in the movement of elevation.[1] Stalagmitic deposits and talus slopes also occasionally mask the true surface of a cliff face. On this account it is necessary to exercise great caution in collecting from raised coral islands to avoid the possibility of mistaking recent fringing material for the older nucleus of the island. This difficulty can usually be overcome by taking certain precautions which have been employed by the leaders of the expeditions mentioned below.

It is often noticed that fringing reefs most commonly occur on the leeward side of an island; while on the windward side not only is no fringing reef formed, but the sea makes inroads into the older limestone, forming lines of beach-erosion at various heights. It is also found that in some of the islands examined natural sections or ravines occur, and these often cut through any superficial material, exposing the older rocks. Advantage was taken of these natural features in making the collections, while Mr. E. C. Andrews took the additional precaution of blasting into the solid rock in making his collections from the Fijis.

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[1] It would perhaps be better to use the term "negative movement of the shore line."

Collections which have been examined. — The materials for the present inquiry have been obtained by taking selected specimens from the collections of the expeditions about to be described; the specimens have been analyzed chemically with a view to determining to what extent dolomitization occurs in upraised coral islands, and many microscopic sections have been made to illustrate the structural and mineralogical changes which have arisen since the formation of the rocks.

In 1897–98 an expedition was made by Dr. C. W. Andrews, one of the officers of the British Museum (Nat. Hist.) to Christmas Island, in the Indian Ocean. The expenses of this expedition were defrayed by Sir John Murray, and Dr. Andrews remained on the island for about ten months, surveying and making extensive botanical, zoölogical, and geological collections.

On his return to England Dr. Andrews gave a preliminary account of his researches before the Royal Geographical Society.[1]

Since then he has prepared a monograph on the island, and this was published in 1900 by the Trustees of the British Museum.

In 1898 ten selected limestones from the island were placed in my hands for chemical and mineralogical examination, and a short account of the results obtained was incorporated in the published monograph, but it was thought advisable to make a much more extensive examination of the limestones to render more complete our knowledge of the chemical and mineralogical composition of the island. This I have been able to do through the kindness of Professor Judd in obtaining the consent of the Trustees of the British Museum (Nat. Hist.); and I wish here to record my thanks to Dr. Andrews for much help in going over the collection with me and verifying the exact locality of each specimen.

Toward the end of 1897 Mr. Alexander Agassiz, who has had so much experience among coral reefs, commenced a cruise in the "Yaralla" among the islands of the Fiji archipelago. The results of his observations were published in 1899.[2]

At the conclusion of this voyage he organized an expedition to examine in more detail certain of the upraised coral islands of the Fijis, with special reference to the Eastern or Lau group. This expedition was undertaken by Mr. E. C. Andrews, of Sydney University, who made a survey of several of the islands, and collected specimens from the cliffs and terraces. His results were published in November, 1900.[3]

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[1] Geographical Journal, January, 1899.

[2] Bull. Mus. Comp. Zoöl., Vol. XXXIII., 1899.

[3] Bull. Mus. Comp. Zoöl., Vol. XXXVIII., 1900.

In 1899–1900 Mr. Agassiz made a further expedition to the Pacific in the "Albatross," visiting the Paumotus, the Tonga or Friendly Islands, and Guam in the Ladrones.[1] Through arrangements made with Professor David and Mr. Agassiz, by Professor Judd, I have been able to examine a small selection of the limestones collected by Mr. E. C. Andrews in the Fijis, and by Mr. Agassiz in the Paumotus, Tongas, Ladrones, etc.

Professor David, on his first expedition from Sydney to Funafuti, visited Niue (Savage Island), and collected limestones from ravine sections and from faces of the raised terraces. These specimens I have examined, and during a recent visit to England Professor David was so kind as to make sketches of the island for me, illustrating the horizons from which the limestones were collected.

Throughout this work I have received from Dr. Cullis, who has had considerable experience with the Funafuti specimens, valuable advice, which I am anxious to acknowledge. I am also indebted to Mr. Frederick Chapman for the specific identification of some of the Foraminifera, while Mr. Franklin T. Barrett and Mr. C. Davies Sherborn have helped me with many valuable suggestions. To Professor Judd my best thanks are due, not only for giving me the opportunity of making this research, but also for valuable help and advice throughout the progress of the investigation.

HISTORICAL INTRODUCTION. — The very early work of Hatchett[2] dealt with the chemical composition of the skeletons of various organisms, including corals, but his analyses were only qualitative, and his results are only distantly related to the present inquiry. Many years elapsed before another investigator published any results bearing on corals or coral reefs.

The next contribution was from Prof. J. D. Dana — Geologist to the United States Exploring Expedition (Wilkes), 1837–42 — who made an extensive collection of corals and coral rocks from the islands visited during the voyage, including limestones from the raised coral island of "Metia" (Makatea). The specimens were analyzed by Benjamin Silliman, Jun., and Professor Dana made a first reference to the results in an address to the Association of American Geologists and Naturalists, at Albany, in 1843.[3] The work was incomplete, and no analyses were

[1] Mem. Mus. Comp. Zoöl., Vol. XXVI., No. 1, 1902, and Vol. XXVIII. 1903.

[2] Chas. Hatchett, Transactions Royal Society, Vol. XC., 1800, p. 327.

[3] American Journal of Science and Arts, Vol. XLV. 1843, p. 120.

given, but Dana recorded the remarkable fact that in some of the corals and coral rocks Silliman had found a considerable amount of magnesium carbonate.

In the following year (1844), at the Washington meeting of the same Association,[1] Dana again referred to the presence of magnesia in some of the corals, and announced the further discovery by Silliman of a certain amount of calcium phosphate in the specimens analyzed. Silliman's early analyses were faulty, but he corrected them in a later article,[2] and also in the appendix to the report upon the United States Exploring Expedition, "Zoöphytes" (1846), p. 712.

Silliman's analyses included specimens of most of the reef-forming corals. Their hardness and specific gravity led Professor Dana to conclude that the stony corals consisted of aragonite and not of calcite, — a conclusion which was subsequently confirmed by Gustav Rose and Dr. H. C. Sorby.

The general result of Silliman's analyses, showing the limits of variation in the composition of the specimens, was given at the conclusion of his paper, and may be stated as follows: —

Calcium carbonate	90–97	per cent.
Fluorides, phosphates, silicates . . .	$\frac{1}{4}$–$2\frac{1}{2}$	" "
Organic matter	2–8	" "

Silliman's paper did not include his analyses of the coral rocks from the raised island of Makatea. These were given in Professor Dana's work.[3] The analysis of one specimen was as follows: Calcium carbonate, 61.93 per cent, magnesium carbonate, 38.07 per cent; another gave 5.29 per cent of magnesium carbonate, while the corals themselves contained very little. In the same work Dana quoted analyses of coral sands, and showed that their composition was not different, as regards the magnesia, from that of the corals. The coral sands from the Straits of Balabac gave calcium carbonate, 98.26 per cent, magnesium carbonate, 1.38 per cent, alumina, 0.24 per cent, phosphoric acid and silica, a trace. Professor Dana quoted the analyses from Metia as an instance of dolomitization during the consolidation of the rock beneath sea water, and it was upon the analyses from this island that he based his well-known theory of dolomitization.

In 1847 a paper appeared in the Quarterly Journal of the Geological Society, written by the Rev. W. B. Clarke, on the Geology of the Island of Lafû, one of the Loyalty Group, east of New Caledonia, in the South Pacific Ocean.[1] The paper contained no analyses, but consisted mainly of a short description of this raised coral island, some parts of which have been elevated to a height of 250 feet, while a terrace at the level of 80 feet marked a pause during the elevation. The author stated that the corals from the highest part of the island were altered and decomposed, while those near the sea level were quite fresh and unchanged.

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[1] American Journal of Science and Arts, 1844, Vol. XLVII., p. 135.

[2] American Journal of Science and Arts, 1846, 2nd Series, Vol. I., p. 189.

[3] Geology of the United States Exploring Expedition, J. D. Dana, 1849, p. 153.

In the year 1880 Prof. A. Liversidge[2] published an account of five analyses of some specimens from the South Sea Islands. These included two specimens, — one of a coral from the New Hebrides, the other of a coral limestone from Duke of York Island, both collected *in situ.*

In the analyses the constituents were expressed as oxides, but if the amounts of calcium and magnesium are given as carbonates, they are rendered more comparable with my own analyses, and are approximately as follows: —

Reef-coral, New Hebrides	
Calcium carbonate	97.54
Magnesium carbonate	.17
Sodium chloride	1.02
Silica	.72
Alumina and iron sesqui-oxide	.23
Hygroscopic moisture	.26
	99.94

Coral-rock, Duke of York Island	
Calcium carbonate	93.025
Magnesium carbonate	1.808
Soda	.848
Potash	.983
Silica	.789
Alumina and iron sesqui-oxide	1.973
Organic matter	.500
Hygroscopic moisture	.012
	99.938

Mr. W. O. Crosby has given a very interesting sketch of the elevated coral reefs of Cuba.[3] He noted that the older parts of the island consist of eruptive rocks and slates, that a series of fringing reefs invests the island at various levels up to nearly 2000 feet, and that the highest and oldest reef is no less than 1000 feet thick.

In 1885 Mr. H. B. Guppy read a paper before the Royal Society of Edinburgh[4] on the structure of the Solomon Islands, based on a considerable personal survey of the group. He described the islands as usually having a volcanic peak as a nucleus; over this was found a consolidated volcanic mud derived from the subjacent volcano, and mixed with calcareous organisms such as Foraminifera. This was usually succeeded by foraminiferal limestones composed of calcium carbonate to the extent of 75 to 85 per cent, the remainder consisting of insoluble matter. Raised coral reefs were found by him resting either on the foraminiferal limestones or on the volcanic muds. Although some of the larger islands have been elevated as much as 10,000 feet, Mr. Guppy never found the raised reefs above the level of 600 feet, and they were never more than 150 to 200 feet in thickness.

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[1] Q. J. G. S., 1847, Vol. III., p. 61.

[2] Royal Society of N. S. W., October 6, 1880.

[3] Proceedings of Boston Society of Natural History, 1883, Vol. XXII, pp. 124–130.

[4] Transactions Royal Society of Edinburgh, 1885, Vol. XXXII., pp. 545–581.

Most of the analyses, made for Mr. Guppy by Dr. Leonard Dobbin, were of the volcanic muds, but two analyses of coral limestones were added. In one from the Shortland Islands the amount of calcium carbonate was 95.76 per cent; the remainder, 4.24 per cent, consisted of insoluble residue. Another specimen from Choisel Bay gave, on analysis, 94.19 and 5.81 per cent of calcium carbonate and insoluble residue respectively.

In a paper read before the Geological Society, in 1891, Mr. Jukes Brown and Professor Harrison[1] gave a description of the geology of Barbados. They stated that no volcanic rocks occurred, that there was no evidence of subsidence, that six sevenths of the surface of the island were covered with coral rock, having a maximum thickness of 260 feet, and that terraces occurred up to a height of 1100 feet.

The following are the results of nine analyses of some of the raised coral limestones: —

	Calcium Carbonate.	Magnesium Carbonate.	Calcium Phosphate.	Ferric Oxide and Alumina.	Silica and Clay.	Loss on Ignition.	Total.
I.	95.78	2.01	trace	2.27	.05	—	100.11
II.	93.38	2.05	.05	.78	3.10	.70	100.06
III.	96.52	1.74	—	.64	1.20	—	100.10
IV.	99.01	.56	.13	.35	.20	—	100.25
V.	98.09	1.25	.07	.27	.48	—	100.16
VI.	98.80	.87	trace	.19	.29	—	100.15
VII.	97.26	2.44	trace	.17	.13	—	100.00
VIII.	97.50	C_aO .41 1.11	.21	.05	.91	.26	100.45
IX.	84.89	1.48	.04	2.24	9.48	2.01	100.14

I. Marl near Bennett's, 400 ft.
II. 635 ft.
III. 635 ft. Plumtree Gully.
IV. 650 ft.
V. Ellis Castle Well, 130 ft. from the surface.
VI. Grove's hard limestone.
VII. Castle Grant limestone.
VIII. Base of coral rock near Codrington.
IX. Crystalline concretionary rock from shaft at Cane Garden.

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[1] Q. J. G. S., 1891, pp. 197–246.

At the conclusion of their paper a general statement was given of other localities from which raised coral limestones have been described.

1. *Guadaloupe.* — This island is volcanic on the western side, and has coral reefs on the east, which are found up to a level of 1300 feet.

2. *Antigua.* — Volcanic rocks occur on the west and reefs on the eastern side up to a height of 300 to 400 feet.

3. *Barbuda.* — Coral limestone alone is found, and reaches a height of 117 feet.

4. *Jamaica.* — Raised reefs are never found above 100 feet, but the massive white limestone of the island, which is 2000 feet thick, and covers six sevenths of the surface, contains corals, and probably its upper part is raised reef.

On June 21, 1891, Mr. J. J. Lister read a paper before the Geological Society on the Geology of the Tonga or Friendly Islands.[1] No analyses of limestones were given, but the paper contained an interesting account of the structure of the group, including three islands, Eua, Vavau, and Tongatábu, visited subsequently by Mr. Alexander Agassiz.[2] Mr. Lister distinguished three kinds of islands.

(*a*) Purely volcanic islands.

(*b*) Those having a stratified volcanic base, since elevated, and with or without limestones.

(*c*) Islands entirely of reef origin.

The islands containing limestones were generally found to be characterized by definite terraces at different levels. Mr. Lister concluded that the islands of the Tonga group have probably grown on banks of volcanic origin laid out in shallow water, and that there was no necessity to call in the hypothesis of subsidence to account for their formation.

Dr. G. J. Hinde contributed a short note in 1893 to the Geological Society on specimens of raised limestones from New Hebrides.[3] He quoted no analyses, but microscopically examined limestones from heights of 346, 500, and 1274 feet. They were found to be made up of nullipores (Lithothamnion), corals, and Foraminifera, and there was no evidence of their having had a deep-water origin.

Among those who accompanied the first expedition to Funafuti was Mr. Stanley Gardiner, who has recently published an account of the atoll, and observations on the raised reefs of the Fiji Islands [4] to which Dr.

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[1] Q. J. G. S., 1891, pp. 590–616.

[2] Analyses from these islands are given in the body of the present paper.

[3] Q. J. G. S., 1893, pp. 230–231.

[4] Proceedings of the Cambridge Philosophical Society, Vol. IX., pt. viii. p. 417.

Pollard contributed some analyses of limestones from Namuka, Fulanga, and Kambara. These limestones all contained a fair proportion of magnesium carbonate.

Namuka.

White Rock	
Calcium carbonate	78.6
Magnesium carbonate	21.5
	100.1

Red Rock	
Calcium carbonate	85.2
Magnesium carbonate	6.7
Ferric oxide and alumina	4.2
Silica	3.5
	99.6

The limestones from Kambara and Fulanga yielded respectively 19.8 and 10.7 per cent of carbonate of magnesium.

References to the earlier expeditions of Mr. Alexander Agassiz among coral reefs are now given in chronological order: —

1878 West Indies. Bull. Mus. Comp. Zoöl., Vol. V., No. 1.
1883 The Tortugas and Florida Reefs. Mem. Am. Acad., Vol. XI., p. 107.
1888 West Indies. Three Cruises of the "Blake," Vol. I., p. 66.
1889 Hawaiian Islands. Bull. Mus. Comp. Zoöl., Vol. XVII., p. 121.
1892 The Galapagos Group. *Ibid.*, Vol. XXIII., No. 1.
1894 Bahamas and Cuba. *Ibid.*, Vol. XXVI., No. 1.
1895 Bermudas. *Ibid.*, Vol. XXVI., No. 2.
1896 Florida. *Ibid.*, Vol. XXVIII., No. 2.
1898 Great Barrier Reef of Australia. *Ibid.*, Vol. XXVIII., No. 4.
1898 Fiji. American Journal of Science, February, 1898, p. 113.

His later expeditions, together with those of Prof. T. W. Edgeworth David, Dr. C. W. Andrews, and Mr. E. C. Andrews have been referred to; but as their collections form the subject-matter for this paper, their published reports will be more particularly noticed in dealing with the microscopical and chemical results obtained from an examination of the collections from the several islands. Mr. R. L. Sherlock has recently examined many of the thin sections, whose microscopical characters are described in this paper, and has identified and named the fossils they contain.[1]

CHEMICAL METHODS. — Before deciding on the quantitative methods to be employed in the chemical examination of the collections, a considerable number of qualitative analyses were made with a view to determining all the compounds likely to be present in the rocks, and also to obtain an idea of the proportions of the different constituents. It was found that the most important constituent was calcium carbonate, that many of the rocks contained a considerable amount of magnesium carbonate, and that calcium phosphate was always present, but never in large quantity.

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[1] Bull. Mus. Comp. Zoöl., 1903, Vol. XXXVIII.

It was also noticed that some of the less altered rocks contained organic matter, that the amount of insoluble residue was as a rule almost inappreciable, and that traces of ferric oxide, alumina, and silica were sometimes found, together with occasional slight reactions for chlorides and sulphates.

These preliminary results serve to show that the calcium and magnesium carbonates constitute practically the whole of the rocks, and this circumstance determined the methods of analysis eventually adopted.

The two methods used were substantially identical with those which have been employed by Dr. Cullis, Mr. Hart-Smith, and myself in the chemical analysis of the Funafuti boring. The details of the gravimetric method may be briefly stated: —

A specimen was prepared for analysis by rejecting the external part which might contain adventitious material. A piece of the more central portion of the limestone, reduced to a powder in an agate mortar and carefully sampled, was washed with boiling water to remove any soluble organic or inorganic matter which might be present, but this amount was found to be negligible. The powder was then dried at 100° C., and for a complete analysis two portions were weighed out.

1. In the first portion the proportions of calcium and magnesium carbonates were estimated. About .8 gram was taken, the calcium precipitated in the ordinary way as oxalate, dissolved and reprecipitated to free from magnesium, and after the careful addition of a few drops of sulphuric acid, heated and weighed as calcium sulphate.

The magnesium was determined from the filtrate by precipitation as phosphate, and was weighed as magnesium pyrophosphate.

2. As insoluble matter and calcium phosphate were present in very small quantity, 10 grams of the limestone were usually taken, dissolved in dilute hydrochloric acid, and filtered through a tared filter paper. The filtrate contained the phosphate, while the insoluble matter, organic and inorganic, remaining on the filter paper, was dried and weighed. By burning off the organic residue, the amount of inorganic insoluble matter was obtained.

The phosphate in the solution was estimated by precipitating with ammonium molybdate at 40°, dissolving the precipitate in the minimum quantity of ammonia and precipitating as magnesium phosphate by magnesia mixture, and weighing as magnesium pyrophosphate.

Owing to the slight solubility of magnesium phosphate in water, care was taken to keep the bulk of the solution as small as possible.

About fifteen of the specimens from various islands were analyzed gravimetrically as above, but it was felt to be unnecessary to deal with all the limestones — nearly two hundred in number — in the same way, if some volumetric determination could be employed which would be at once more rapid than the gravimetric method, and yet give fairly accurate results.

Such a method has been much used in connection with the Funafuti boring, and was agreed upon by a Chemical Committee of the Royal Society. The details were devised by Professor Tilden, and were first worked out by Mr. J. Hart-Smith, under Dr. Tilden's supervision.

In this volumetric analysis only the calcium is determined. The principle on which the method is based is as follows: —

The addition of a solution of ammonium oxalate to a sufficiently dilute solution containing calcium and magnesium salts, to which a solution of ammonium chloride and ammonia has been added, will precipitate calcium oxalate practically free from magnesium oxalate.

If a known amount of ammonium oxalate is added, — more than is necessary to precipitate all the calcium, — the excess of ammonium oxalate may be determined by titration with potassium permanganate solution. The details of the method may be stated thus: —

Large quantities of the following solutions were made up: —

1. Potassium permanganate, decinormal solution.
2. Ammonium oxalate, one gram in 50 cubic centimeters.
3. Ammonium chloride and ammonia, one gram of each in 25 cubic centimeters.
4. Hydrochloric acid, one gram in 25 cubic centimeters.
5. Sulphuric acid, one gram in 10 cubic centimeters.

About .3 gram of the powdered limestone was dissolved in 25 cubic centimeters of hydrochloric acid solution, and any insoluble residue, if present, was filtered off.

To the solution were now added 150 cubic centimeters of distilled water, and then, from a pipette, 25 cubic centimeters of ammonium chloride and ammonia.

If any appreciable quantity of phosphate were present, a white precipitate was formed, which was filtered off, and the amount of phosphate estimated separately as above.

In most cases no precipitate, or only the slightest turbidity, was noticed, and after the solution was heated, 50 cubic centimeters of the standard solution of ammonium oxalate were run in from a calibrated burette. This precipitated all the calcium as oxalate, and left an excess of oxalate in the solution. The beaker of solution was then cooled to the temperature of the air and poured into a calibrated flask of 250 cubic centimeters' capacity, and filled with distilled water up to the mark in the neck. The solution was next filtered through a dry filter paper, and 100 cubic centimeters of the clear filtrate measured out from a calibrated burette. To this were added 25 cubic centimeters of dilute sulphuric acid; the mixture was then warmed to about 50° C., and titrated with standard permanganate solution from a calibrated burette.

The value of the permanganate had been previously obtained by means of pure ferrous ammonium sulphate and its equivalent in the standard ammonium oxalate solution, determined by titration. With these data the amount of oxalate which had combined with the calcium could be estimated, and from that the percentage of calcium carbonate present in the rock was obtained. When phosphate or insoluble residue was present in determinable quantity, the amounts were ascertained separately by the methods already described, and the percentage quantity added to that of the calcium carbonate. The amount of magnesium carbonate in the rock was then represented by the difference between this figure and one hundred.

This method was used by Mr. Hart-Smith in making determinations of specimens from the Funafuti core. Later, I had the opportunity of making a number of analyses from different depths of the same boring. With both of us the method has yielded consistent and fairly accurate results, and it is this means of analysis which I have mainly employed — confirmed here and there by gravimetric determinations — in working on the limestones from the islands about to be considered. In order to test the method more fully, and with a view to demonstrating to what extent the results yielded by it may be relied on, I made a series of determinations in duplicate, and another series in which gravimetric and volumetric analyses of similar specimens were compared. An examination of the results showed that the maximum difference in 27 determinations of calcium carbonate in duplicate from different limestones was .8 per cent, while the average difference was rather less than .4 per cent. Similarly a comparison of gravimetric and volumetric results of calcium carbonate from 15 different rocks showed a maximum difference of .93 per cent and an average difference of rather less than .5 per cent.

MICROSCOPICAL METHODS. — In examining the thin sections of the limestones, my attention was directed not so much to the identification of the organisms (these have been described by Mr. R. L. Sherlock[1]) as to the determination of their mineral character, and the changes they and the matrix have undergone. It was as a rule sufficient for my purpose to be able to recognize corals, echinoderms, and molluscan shells, to distinguish between Halimeda and Lithothamnion among the calcareous algæ, and to recognize a few of the more important Foraminifera, such as Polytrema, Amphistegina, Heterostegina, Carpenteria, Orbitolites, Globigerina, etc.

The precise identification of the mineral structure of the organisms, of the crystalline material subsequently deposited on them, and of the general character of the matrix, was not always an easy matter.

In fibrous crystals it was often difficult to distinguish between aragonite and calcite, while occasionally difficulties arose in differentiating calcite from dolomite.

The characters usually relied on for the identification of aragonite are its occurrence in long prismatic crystals, its specific gravity (2.92), and its biaxial character. In contrast with these properties, calcite usually occurs in rhombohedra or scalenohedra, its specific gravity is 2.72, it has a strong rhombohedral cleavage, and it gives a well-marked uniaxial interference figure. Dolomite can, as a rule, be distinguished from calcite[2] by its occurrence in simple unit rhombohedra often showing zoning, its specific gravity (2.9), its higher refraction, and the fact that its cleavage is usually less marked than that of calcite. As a rule, these tests were sufficient for the identification of calcite and dolomite, but gave no certain distinction for aragonite. Organic fragments were often found coated with an encrusting deposit of small radiating crystals, which were too small to allow of a specific gravity determination, while the interference figures given by these minute bundles of crystals were always unsatisfactory. When fibrous crystals were found in optical continuity with the fibers of a coral, there was little doubt that the two substances were identical. In this connection it may be mentioned that a determination of the specific gravity of a coral from Niue, at a height of 80 feet, yielded a result of 2.81.

Where no optical continuity could be traced between the deposited crystals and the coral fibers, some other critical test was desirable in order to distinguish between calcite and aragonite.

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[1] Bull. Mus. Comp. Zoöl., 1903, Vol. XXXVIII.

[2] Renard, Bull. Acad., Belgique, May, 1879, Vol. XLVII., No. 5.

Such a method has been described recently by W. Meigen.[1]

The method consists in boiling the powdered substance for a few minutes in a solution of commercial cobalt nitrate, when a lilac-red precipitate of basic carbonate of cobalt indicates the presence of aragonite, while calcite remains unaffected, or in the presence of organic matter becomes yellowish. Barium and strontium, but not magnesium carbonates, give the same result as aragonite, while calcium phosphate produces a blue precipitate.

By means of this reaction Meigen distinguished aragonite from calcite in various animal and vegetable secretions of calcium carbonate.

A few of the results of his determinations are here enumerated :

Aragonite Organisms : —

CALCAREOUS ALGÆ — Halimeda.
CORALS — Heliopora, Montipora, Madrepora, Millepora, Goniastrea, Podobacia, Galaxea, Fungia, Porites, etc.
LAMELLIBRANCHS — Pholas, Cardium, Lucina, Mya, Cytheraea Unio (inner layer of shell), Trigonia (inner layer of shell).
GASTROPODS — Helix, Pupa, Bulimus, Cyclostoma, Natica.
CEPHALOPODS — Nautilus, Spirula, Sepia.

Calcite Organisms : —

CALCAREOUS ALGÆ — Lithophyllum, Lithothamnion.
CORALS — Isis, Tubipora, Cystiphyllum, Anabacia.
FORAMINIFERA — Polytrema, Nummulites.
WORMS — Serpula.
ECHINODERMS.

Meigen's method was tested by me in the following way, and found to give satisfactory results : —

First, the pure minerals, calcite and aragonite, were treated separately, both powdered and in crystals. In each case the calcite was quite unaffected after long boiling, while the pink stain on the aragonite was deeper in the powder than on a crystal surface. A coral sand containing gastropods, echinid spines, and Foraminifera was next treated, and it was found that the gastropods stained deeply, but the echinid spines and Foraminifera were unaffected. A polished slice of a limestone was taken and boiled for half an hour with cobalt nitrate solution. The limestone consisted of coral fragments, gastropods, echinid spines,

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[1] Centralblatt für Mineralogie, 1901, pp. 577–578.

Halimeda, etc., cemented with a large quantity of fibrous calcium carbonate. After treatment with cobalt nitrate the slice was mounted, polished surface downward, on a glass slip, and the slice ground down till it was quite transparent. A cover-glass was then mounted on the section, and it was found that the corals, gastropods, and Halimeda were all stained red, the solid walls of the coral being less deeply stained than the septa. The echinid spine was quite unaltered, and no sign of staining was seen on the stalagmitic fibrous calcium carbonate forming the cementing ground mass of the rock. This cement is thus shown to consist of *fibrous crystals of calcite.* It remained to test the prismatic crystals which were occasionally found in optical continuity with coral fibers. A slide showing this was prepared as above described, and it was then found that the septa of the coral and the "dark line" were stained a deep red, the solid parts of the coral and the prismatic crystals in continuity with the coral fibers were colored a lighter pink, while some clear crystalline calcite which filled other cavities was entirely unaffected. The *prismatic crystals in continuity with coral fibers* were thus shown to be *aragonite.*

In discriminating between calcite and dolomite, there was, as a rule, not so much difficulty. The more idiomorphic character of dolomite crystals and their frequent zoning usually served to distinguish them, and when the two minerals occurred associated together, the higher refractive index of dolomite gave it a relief which was a useful diagnostic character. In cases of doubt Lemberg's[1] test was applied, with satisfactory results.

The test consists in applying to the exposed surface of a thin section for about 5 to 15 minutes a solution containing a mixture of aluminium chloride and haematoxylin. Under these circumstances dolomite and brucite are unchanged, but a deposit of aluminium hydrate forms on the less stable calcite, and is stained a reddish purple by the haematoxylin.

The staining solution is prepared by dissolving four parts of dry aluminium chloride in 60 parts of water, and adding six parts of logwood (Haematoxylin campechianum). The whole was boiled and stirred for 25 minutes, and made up to the same bulk after filtration. It is not advisable to allow the staining solution to remain on the rock for more than 15 minutes, as dolomite is slowly acted upon, and also a thicker layer of alumina is deposited on the calcite, which is more easily peeled off and shrinks more on drying. After being stained, the section is dried, Canada balsam, somewhat diluted with ether, is poured upon it, and the cover-glass adjusted.

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[1] Zeitschrift der deutschen geologischen Gesellschaft, 1888, Vol. XL., p. 357.

The works of Gustav Rose [1] and of Dr. H. C. Sorby [2] have dealt largely with the mineralogical constitution of various organisms, and to these papers, especially that of Dr. Sorby, I am indebted for many helpful suggestions.

One of the results of their researches went to show that the mineral composition of most of the reef-forming corals is aragonite. This view remained practically unquestioned till 1900, when Miss Agnes Kelly's paper [3] appeared "On a new form of calcium carbonate," to which she gave the name of conchite. The skeletons of the organisms which have hitherto been described as being aragonite are claimed by Miss Kelly to consist in reality of conchite. It is said to differ from aragonite in its uniaxial character and the lower temperature at which it passes over into calcite and to have a refractive index intermediate between those of calcite and aragonite.

Quite recently, however, Reinhard Brauns,[4] in a paper on the relation of conchite to aragonite, states that while there appear to be certain differences, at present there is not positive evidence sufficient to warrant the making of a new mineral species.

Another paper on ktypeite and conchite, by Henrich Vater,[5] has recently appeared, in which he agrees with R. Brauns in saying that conchite is probably identical with aragonite.

As the question is still in doubt, I have used only the term aragonite for all material which stains with cobalt nitrate, but if Miss Kelly should eventually be proved to be correct in her contention, those crystals which are in optical continuity with coral fibers would have to be known as conchite.

The details of the chemical and microscopical analyses from each island will now be given. It is to be noted that gravimetric analyses are recorded to two places of decimals, while the results of volumetric determinations are given only to the first decimal place.

A certain number only of the limestones have been sliced, and the details of their structure and composition are given below. In the descriptions of the thin sections under the microscope the term "mud" is frequently employed to express the appearance of the finest calcareous detrital material and is not intended to convey the idea of an argillaceous sediment. In this part of the work I have endeavored to record the facts so far as I have been able to observe them, leaving any theoretical bearing these may have to be dealt with at the conclusion of the paper.

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[1] Abh. K. Akad. d. Wiss. in Berlin, 1858.

[2] Pres. Address to Geol. Soc., 1879.

[3] Bav. Academy, May, 1900, and Min. Mag., June, 1900.

[4] Centralblatt für Mineralogie, 1901, pp. 134–135.

[5] Zeitschrift für Krystallographie und Mineralogie, 1901, Vol. XXXV., p. 149.

II. Chemical and Microscopical Results.

1. Pacific Ocean.

A. The Fiji Group (Eastern or Lau Division).

Mango. — Mango is an island subcircular in shape, and about 3½ miles in diameter, situated in latitude 17° 25′ S. and longitude 179° 10′ W. Mr. E. C. Andrews's published descriptions,[1] with maps and sections, give a good idea of the general structure of the island. It consists of an elevated ring of limestone, with bold cliffs often over 400 feet in height. Patches of recently raised reefs occur here and there on the lower slopes, while along the inland cliffs old reefs are met with at levels of 50 and 250 feet, and traces of a terrace occur up to 200 feet in the cliffs on the northern and southern limits of the island. The ring of elevated limestone is now not continuous all round the island, but has been broken through at the north-western and south-eastern margins by very extensive andesitic flows proceeding from two volcanic centers, one in the south-east of the island, the other north-west of its center. The limestone is still further obscured over the central depression by the formation of a considerable deposit of volcanic alluvium. On the north-east of the island there is a small lagoon, connected by a narrow channel with the sea. This depression probably represents a former means of communication between the outer sea and the central lagoon. The limestones which I have examined were collected by Mr. E. C. Andrews from among the older unbedded limestones of the sea-cliffs at definite heights above high-water mark. They are all younger than the basal limestones which are exposed here and there. These basal limestones dip at 15°–20°, and are interbedded with "soapstone."

Chemical. — Most of the rocks consist of highly dolomitic limestones; but at a few points, notably, at 370, 310, and 298 feet, limestones occur with only 4.9, 9.7, and 10.7 per cent of magnesium carbonate respectively. At a height of 280 feet a rock is found in which magnesium carbonate is represented to the extent of 27.3 per cent. An interesting point is that most of the analyses yield from 38 to 42 per cent of magnesium carbonate, but none of them approach nearer to the composition of a true dolomite. Calcium phosphate is found in most of the rocks, but usually only in traces, as .29 per cent was the maximum amount obtained.

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[1] Bull. Mus. Comp. Zoöl., 1900, Vol. XXXVIII., pp. 17–20.

Insoluble residue is present in exceedingly small quantities, except where the limestones are associated with volcanic rocks. This association will explain the unusually high value of 4.03 per cent obtained from the limestone at 420 feet. The adjoined tabular statement gives the details of the analyses, and the accompanying diagram represents the proportion of calcium to magnesium carbonate, expressed graphically in the case of three rocks which occur in vertical succession in one cliff face. The shaded area represents the percentage of magnesium carbonate, the unshaded area representing calcium carbonate. The dotted line is drawn at a point representing 46 per cent of magnesium carbonate, the proportion represented in a true dolomite. The curve is obtained by joining all points at which specimens were collected in vertical succession from a cliff face. The remaining specimens were collected at the stated heights from isolated spots in various parts of the island, but are interesting as showing the occurrence of dolomitic and non-dolomitic limestones at different heights in the island.

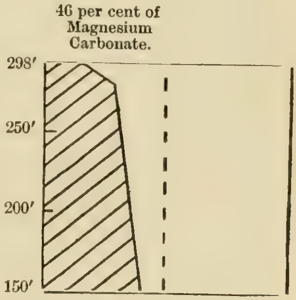
These diagrams, therefore, do not represent completely the chemical composition of all the rocks between the highest and lowest specimens, but are used as a convenient means of presenting at a glance the detailed results of the analyses at stated heights.

Microscopical. 510′. — A thoroughly dolomitized rock in which the organisms are nearly obliterated. Some of the cavities are lined by a deposit resembling agate. It consists of 6 layers of sharply defined crystals alternately dolomite and calcite, as shown by staining; the central layer filling the remainder of each cavity consists of broad platy crystals of calcite. Some of the dolomite rhombohedra have dark opaque irregular centers, which by staining with Lemberg's solution are proved to consist of calcite.

400′. — A fine-grained dolomitic limestone, in which organisms such as Lithothamnion and Carpenteria are found, only slightly altered, while others, such as Amphistegina (?) are quite removed, and their former presence can only be suggested by the similarity of the shape of the cavities to the external boundary of the organisms. Many casts of coral occur, in which the septa are represented by a gray "silt" lined with

Height.	Calcium Carbonate.	Magnesium Carbonate.	Insoluble Residue.	Calcium Phosphate.
510′	59.4	40.6	—	—
435′	59.29	40.70	—	—
420′	84.2	11.8	4.03	—
410′	62.7	37.3	—	—
400′	60.66	38.50	—	—
380′	62.9	37.1	—	—
370′	94.9	4.9	.16	—
350′	69.5	30.2	.34	—
335′	59.5	40.5	—	—
330′	58.7	41.3	—	—
320′	58.3	41.7	—	—
310′	90.16	9.70	.10	.29
300′	61.2	38.8	—	—
298′	88.0	10.7	1.26	—
290′	59.5	40.5	—	—
280′	72.3	27.3	—	—
250′	66.0	34.0	—	—
200′	61.2	38.8	—	—
195′	97.2	2.8	—	—
155′	61.7	38.3	—	—
150′	62.3	37.3	—	—
145′	78.6	21.4	1.43	—
105′	63.6	36.4	—	—
73′	75.4	24.6	—	—
40′	60.1	39.9	—	—
20′	57.7	42.3	—	—
6′	60.8	39.2	—	—

MANGO.



clear dolomite. The matrix consists entirely of silt, having a semi-transparent appearance, due to its consisting largely of minute rhombohedra of dolomite. The obliteration or solution of some of the corals and Foraminifera renders the rock somewhat cavernous.

370′. Figure IV. A "coral sand" or limestone, made up of small fragments of Carpenteria, Gypsina, Lithothamnion, and echinid spines. Some organic fragments are entirely recrystallized in clear calcite, the former boundary of the organism being marked by a "dirt line," while the stereoplasm of the corals has been replaced by calcite, and the spaces between the septa filled with "mud." The matrix consists partly of mud and partly of its alteration product calcite.

350′. Interest in this slide centers in the fact that the dolomite rhombohedra consist of three parts, a central rhomb of dolomite, a middle layer of calcite, and an outer one of dolomite. All three layers have quite sharp rhombohedral angles and all are in optical continuity.

335′. The whole of the matrix is dolomitized, as are all the organisms except the central parts of the Lithothamnion. Clear crystals encrusting the fragments of some of the organisms have an outer layer of slightly higher refractive index. This outer layer does not stain, while the central crystal which is slightly rounded, after treatment with Lemberg's solution for half an hour is colored a light pink. This, in conjunction with the evidence of refractive index, seems to suggest that the central layer may be calcite, containing some magnesium, while the peripheral part consists of a purer dolomite.

320′. Figure X. Reference to the figure shows that this slide consists of a longitudinal section of a coral, in which the organism has been converted into dolomite without the complete destruction of its structure. This is shown by the fact that the original borings made in the coral by algæ, and subsequently filled with "mud," still remain in the same position in the coral, with the mud apparently unaltered. Dirt lines mark the original extent of the walls of the septa, and these are now incrusted with clear dolomite crystals. Many cavities are filled with "mud" up to a certain level, and the surfaces of these "dirt floors" are roughly parallel to one another. Other cavities have been filled with large, slightly yellow plates of calcite. Lithothamnion occurs apparently unaltered, but under the high power its tubules are seen to be filled with small dolomite crystals.

310′. This limestone is interesting on account of the occurrence in it of many examples of the foraminifer Orbitoides. Mr. Frederick Chapman has kindly identified it for me as the form *Orbitoides sumatrensis*, a form which occurs in some of the upper limestones of Christmas Island, and to which a Miocene age has been assigned.

Polytrema and Lithothamnion also occur in this rock, which has a matrix consisting largely of "mud," while some of the cavities are lined with scalenohedral crystals of calcite.

300′. A fragmental rock, which, by the thorough dolomitization of matrix and organisms alike, has become clear and crystalline. Lithothamnion partly resists change, and one simple coral is represented by a cast in "mud." No other forms are recognizable; even the "dirt lines" round the boundaries of formerly existing organisms have been recrystallized. Cavities and cracks in the rock are more or less filled with large plates of secondary calcite.

298′. This limestone was probably a beach deposit. It consists of rounded fragments of limestone and dolomite, with other fragments of volcanic origin, probably basalt. These rounded grains are seen to touch one another in places, and are invested with a concentric coating of fibrous calcite, while the remaining space is filled with a mosaic of calcite crystals.

290′. Figure IX. A thoroughly dolomitic cavernous rock, with Lithothamnion and meandrine structures, probably "ghosts" of corals. Secondary calcite fills many of the cavities.

280′. A dolomitic limestone, largely composed of Lithothamnion and Carpenteria. The former is usually unaltered, but the latter has recrystallized in large crystals of clear calcite, and would be difficult to recognize but for the numerous tubules running into the calcite. These tubules have been filled with a "mud," which in places can be seen to have altered to little rhombs of dolomite.

250′. A dolomitic limestone in which meandrine forms, possibly corals, are the only remaining organisms, while many cavities are filled with secondary calcite.

195′. A comparatively fresh limestone with a fine-grained cement of calcite. Carpenteria and Polytrema are the most abundant organisms, but Lithothamnion and echinid spines are also noticed.

105′. A rock in which all the matrix and most of the organisms have been dolomitized. Some specimens of Lithothamnion, however, show that the invasion of dolomite has been only partially effected, as the central parts are still calcite. Meandrine fragments of other organisms also remain as calcite, and a secondary deposit of this mineral fills some of the larger cavities in the rock. Many of the dolomite crystals, especially those formed round the meandrine organisms, have centers of calcite. These centers are sometimes crystalline and rhombohedral in shape, but often consist of irregular inclusions of muddy calcite.

20′. A cavernous dolomite whose appearance suggests that most of the organisms originally present in the rock have been subsequently dissolved. Lithothamnion is still recognizable, although completely dolomitized.

6′ A. A longitudinal section of a dolomitized coral is seen, showing many mud-floors and tubes of algæ. Many of the dolomite rhombs have an outer layer of calcite optically continuous with the dolomite. The larger cavities in the coral have been subsequently filled with broad crystals of calcite.

6′ B. Chiefly consists of a dolomitic cement with sections of Lithothamnion and echinid spines, which, though dolomitized, still preserve their structures. Cavities are lined with a deposit consisting of four successive layers alternately dolomite and calcite, the last layer forming broad calcite crystals completely filling the remainders of the cavities.

6′ C. This dolomitic limestone contains few recognizable organisms. Meandrine forms occur in a dolomitic "mud"; Amphistegina and Orbitolites are very much altered, or represented only by casts, while all stages in the disintegration of Lithothamnion can be seen in this section, the gradual invasion of the organism by dolomite taking place from without inwards, so that in some fragments the outer margin of the organism is obliterated, while the central part appears quite unaltered.

NGILLANGILLAH. — Ngillangillah is a small island near Vanua Mbalavu, in the Exploring Isles, in latitude 17° 10′ S., longitude 179° 2′ W. It is entirely composed of elevated limestone, and reaches a height of 510 feet.[1]

The island appears to consist of masses of coral reef or reef débris, with a bedded limestone underlying the coral rock, not exposed in this island, but seen in Bai Vatu, a few miles to the south. There are traces of three or four separate upheavals visible on the island.[2]

The limestones examined were collected in vertical sequence from one of the cliff faces. Mr. E. C. Andrews is of the opinion that the specimens collected near the sea level belong to younger fringing reefs formed at a late stage of the movement of elevation.

Chemical. — An inspection of the tabulated analyses or the appended diagram will show that the composition of the island from top to bottom is remarkably uniform. All the limestones are dolomitized, and the limits of variation in the amount of magnesium carbonate are very small, the minimum value being 34.6 and the maximum 39.1 per cent. Insoluble residue and calcium phosphate are present only in very minute quantities.

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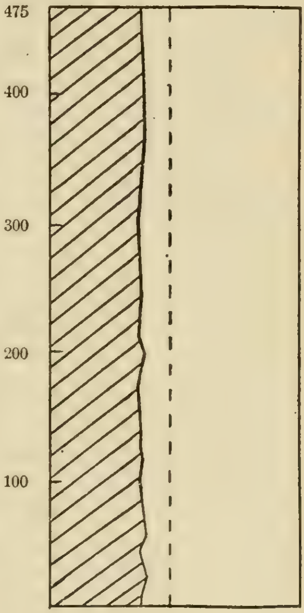
[1] Bull. Mus. Comp. Zoöl., 1899, Vol. XXXIII., p. 90.

[2] Bull. Mus. Comp. Zoöl., 1900, Vol. XXXVIII., pp. 28 and 31.

Height.	Calcium Carbonate.	Magnesium Carbonate.	Insoluble Residue.	Calcium Phosphate.
475′	65.4	34.6	.02	—
405′	63.4	36.6	—	—
365′	63.0	37.0	—	—
305′	64.6	35.4	—	—
250′	63.7	36.3	—	—
215′	64.2	35.8	—	—
200′	62.0	38.0	—	—
175′	67.6	34.9	0.1	—
140′	62.78	36.68	—	.064
127′	63.4	36.6	—	—
120′	62.1	37.9	—	—
100′	63 4	36.6	—	—
90′	63.5	36.5	—	—
55′	61.6	38.3	.07	—
45′	63.6	36.4	—	—
25′	60.9	39.1	—	—
6′	63.3	36.7	—	—

NGILLANGILLAH.



Microscopical. 475′. — The appearance of the section suggests that the rock was a fragmental limestone made up of Lithothamnion and other organisms, largely cemented by an incrusting deposit of radiating crystals of calcite. Subsequently the rock has been dolomitized. In some parts of the rock the matrix was originally "mud," some of which has since altered to more or less clear granular dolomite.

215′. A dolomitic limestone, in which the only recognizable organisms are Amphistegina, altered Lithothamnion, and "ghosts" of corals, now represented by infillings of "mud" between the septa of the vanished corals. The rest of the section consists of clear dolomite, much of which is zoned.

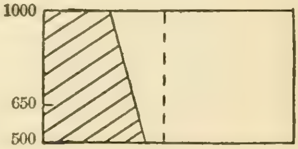
25′. The slide is cut to show a transverse section of a dolomitized coral — Figure VIII. — in which the inner and outer walls of the coral can be traced by "dirt lines." Many of the cavities between the septa are empty, except for a lining of dolomite crystals on the walls, but some are filled with a dark "mud" containing fragments of organisms. This "mud" filled the cavities in which it occurs before dolomitization took place. This is proved by its being in contact with the wall of the coral, and by the layer of dolomite crystals incrusting the "mud" and not the coral wall. Staining with Lemberg's solution shows that in this case the "mud" probably remains as calcite, though in some other rocks it appears to become dolomitized without apparent change. Quite distinct from this dark "mud" is a gray "silt," which is found in the place of the stereoplasm of the coral. This material must have been formed after the dark "mud" was deposited, and after, or as a result of the breaking down of the stereoplasm of the coral. It sometimes occurs in corals preserved in calcite when its composition must be similar, sometimes as in this case there is little doubt that it is dolomitic, as dolomite crystals are seen to have formed within it, and never in the dark "mud" filling the interseptal spaces.

Vatu Vara. — Vatu Vara or Hat Island is in latitude 17° 20′ S., longitude 179° 30′ W.[1]

The island is one mile and a quarter in diameter, its summit is flat (consisting of a small reef), and falls off on each side in steep cliffs. It attains an altitude of 1030 feet, and from top to bottom is composed of limestone. Traces of five uplifts are visible on its ascent; three of these are "terrace" formations, while two are represented by beach erosion lines.

Height.	Calcium Carbonate.	Magnesium Carbonate.	Insoluble Residue.
1000′	74.3	25.5	.20
650′	60.7	39.3	—
500′	58.45	41.47	—

VATU VARA.



Chemical. — Only three specimens have reached me, and they are all dolomitic. The percentage of magnesium carbonate increases from 25.5 at 1000 feet to 39.3 at 650 feet, while at 500 feet it reaches 41.47.

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[1] Bull. Mus. Comp. Zoöl., 1899, Vol. XXXIII.

Microscopical. 1000′. — A fine-grained cavernous dolomite, whose cavities have been filled subsequently with clear secondary calcite, reducing the proportion of magnesium carbonate to 25.5 per cent. The organisms present are Lithothamnion, and possibly Polytrema, while meandrine strings of dolomite crystals, filled in with secondary calcite, suggest the former presence of corals.

650′. A very porcellanous-looking fine-grained dolomite, whose cavities and cracks are filled with secondary calcite. No organisms are recognizable.

500′. A fine-grained silty dolomite, whose organic contents, very much altered, consist of decomposed Lithothamnion and casts of Orbitolites. Cavities in the rock are lined with clearer crystals of dolomite.

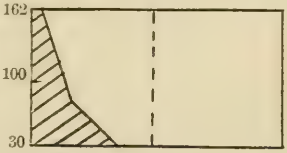
Namuka. — This island is 4½ miles long, and consists of a narrow undulating ridge, rising in places to a height of 240 feet.[1]

It is formed wholly of elevated limestone, and is situated in latitude 18° 50′ S., longitude 178° 35′ W. It forms one of the most southerly islands of the Eastern or Lau group of the Fiji Archipelago.

Chemical. — Only three limestones were available for analysis, of which two were found to be dolomitic. The uppermost specimen, from a height of 162 feet, is a limestone containing only 2.5 per cent of magnesium carbonate, but has .78 per cent of insoluble residue, a high value for a coral limestone unassociated with rocks of other than coral origin. At a height of 75 feet the magnesium carbonate has increased to 17.7 per cent, while no less than 34.5 per cent is found in the lowest rock from a height of 30 feet.

Height.	Calcium Carbonate.	Magnesium Carbonate.	Insoluble Residue.
162′	96.7	2.5	.78
75′	82.3	17.7	—
30′	65.5	34.5	—

NAMUKA.



Microscopical. 162′. — A fine-grained consolidated "mud," formerly full of organic fragments, a few of which remain (Lithothamnion), but nearly all have been replaced by calcite pseudomorphs. The rock is much cracked, the sides of the cracks being lined first with an iron staining and then completely filled from solution by crystals of calcite, projecting from the walls of the cracks and meeting in the center in a notched line, suggesting the "comb" structure in a mineral vein.

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[1] Bull. Mus. Comp. Zoöl., 1899, Vol. XXXIII., p. 57.

75′. The rock contains meandrine organisms (probably "ghosts" of corals), altered Lithothamnion, Foraminifera, and echinid spines. All the organisms, with the exception of the echinid spines, are much dolomitized, and in many cases crystals of dolomite are incrusting the organisms. Between the organic fragments granular calcite occurs in large amount. The limestone was probably originally a fragmental rock, becoming subsequently highly dolomitized. After dolomitization the many spaces in the cavernous dolomite were filled with a clear mosaic of calcite. The echinid spines which had resisted dolomitization have received a secondary deposit of calcite round them in optical continuity with the original organisms.

30′. A similar rock to the last one described, but with the difference that the proportion of dolomitized organisms to secondary calcite is much larger. A good deal of "mud" also occurs as a matrix to some of the organisms. Particular interest centers in one of the organisms, a rather altered Orbitoides which could not be specifically identified. It goes to show, however, that the rock in which it occurs is not later than Miocene in age.

YATHATA. — Yathata is one of the northern islands of the Lau group,[1] and is situated in latitude 17° 15′ S., longitude 179° 30′ W. It rises to a height of 840 feet, and six well-marked terraces occur on its slopes. On the western side of the island a volcanic mass reaches the 500 feet level, scorching and whitening the limestone.

Chemical. — The only specimen available was from near the summit of the island at a height of 800 feet. It consists of a highly dolomitic limestone, with 38.7 per cent. of magnesium carbonate.

Height.	Calcium Carbonate.	Magnesium Carbonate.
800′	61.3	38.7

Microscopical. — Among the organisms which formerly were present in large numbers, only Lithothamnion and Polytrema retain their structure. The remainder are represented by dirt outlines, filled in with clear dolomite crystals. The matrix of the rock is a gray, partly crystalline "mud."

KAMBARA. — Kambara occurs at the southern end of the Lau group in latitude 18° 57′ S., longitude 178° 55′ W. Its structure[2] is very similar to that of Mango. It consists of a rim of elevated limestone, rising to a height of 300 to 350 feet, with a central depression. The island is elliptical in shape, nearly five miles long, with a greatest breadth of three miles. On the north-west face the limestone is broken through by a conical hill 470 feet high, which is of volcanic origin.

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[1] Bull. Mus. Comp. Zoöl., 1900, Vol. XXXVIII., p. 22.

[2] Bull. Mus. Comp. Zoöl., 1899, Vol. XXXIII., p. 98.

Chemical. — The only limestone examined came from a height of 250 feet, and contains 34.5 per cent of magnesium carbonate.

Height.	Calcium Carbonate.	Magnesium Carbonate.
250′	65.5	34.5

Microscropical. 250′. — The matrix of the rock consists largely of a fine gray "mud," which under the high power is in places seen to consist of minute crystals of dolomite. Apparently the organisms have not shared in the dolomitization as, for the most part, they seem to be fresh and unaltered. Carpenteria shows its brown color, Lithothamnion, alcyonarian spicules, and echinid spines are apparently unaltered, while Heterostegina preserves its structure except for small wedge-shaped parts of the shell, which were probably aragonite and have now disappeared.

SINGATOKA (Viti Levu). — This district is on the south-western border of the island of Viti Levu, the largest of the Fiji Archipelago.[1] The locality from which the specimens were collected is at the mouth of the Singatoka River, in latitude 18° 10′ S., longitude 177° 30′ E., where large deposits of upraised bedded limestone, dipping at 15°, form cliffs of 250–300 feet in height. Beneath these limestones a compact blue limestone is found dipping at 50°, while below this occurs an immense block of dolomite, practically perpendicular, and consisting of two hills, 1000 and 1500 feet respectively above the river.

Chemical. — The four specimens analyzed were taken in vertical succession from the upraised bedded limestones, which have a dip of 15°. All the rocks are limestones containing only from 3 to 6 per cent of magnesium carbonate. They are interesting chiefly on account of the relatively large quantity of insoluble matter which they contain. The rock from the reef has a smaller quantity, about 1 per cent, but the three specimens from the cliffs yielded on analysis 1.9, 2.09, and 2.31 per cent respectively of insoluble matter.

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[1] Bull. Mus. Comp. Zoöl., 1900, Vol. XXXVIII., pp. 13–14.

Height.	Calcium Carbonate.	Magnesium Carbonate.	Insoluble Residue.
268′	92.1	6.0	1.90
251′	94.4	4.3	2.31
248′	93.3	4.6	2.09
Reef	95.3	3.6	1.06

Microscopical. 268′. — A foraminiferal consolidated "mud," in which Amphistegina is common. Insoluble material can be recognized in the section.

251′. A cavernous, crystalline rock, containing Gypsina, Carpenteria, and rotaline forms of Foraminifera.

Reef. — A very crumbling rock, made up of fragments of Lithothamnion, Carpenteria, and Amphistegina in a matrix consisting partly of "mud," but mainly of crystalline calcite.

B. Niue.

Niue or Savage Island is a small mass entirely composed of raised coral limestone, situated in latitude 19° 10′ S., longitude 169° 47′ W., about 350 miles east of the Tonga or Friendly Islands. Besides the living reef there are three well-marked raised reefs or terraces at 80, 120, and 200 feet respectively. The highest point of the island is a little over 200 feet, and there is a well-marked central depression or lagoon. I am indebted to Professor David for a description and sketch of the structure of the island. At one part a natural ravine occurs, cutting through the first raised reef into a mass of coral rubble, dipping at 40° and forming the basis on which the second raised reef rests. Professor David, besides collecting specimens from the first, second, and third raised reefs, obtained specimens at intervals of five or six feet up to 70 feet from the ravine of rubble rock.

Chemical. — All the rocks are limestones, with a small quantity of magnesium carbonate, varying in amount from 3 to 8.8 per cent. Gravimetric analysis of a specimen of rubble rock at 53 feet shows that nearly 1½ per cent of soluble organic matter is present, and since all the rocks are comparatively unaltered, it is probable that some organic matter is present in all the specimens. Since the magnesium carbonate is estimated by difference, this will have the effect of making the results for that compound slightly too high. Insoluble inorganic matter is present only in minute quantities, and the same remark holds good of the amount of calcium phosphate present in the rocks.

Microscopical. 80′. *First Terrace.* — A transverse section of a large compound reef-forming coral (Figure 1.). The coral is very fresh, showing the "centers of calcification" and spicular structure. Most of the cavities are empty, but some are filled with a dark "mud," while in others long prismatic, rather muddy crystals of aragonite have arisen by alteration of the "mud." These crystals of aragonite are seen to be crystallographically continuous with the spicules, making up the stereoplasm of the coral.

Height.	Calcium Carbonate.	Magnesium Carbonate.	Insoluble Residue.	Calcium Phosphate.
200′	94.2	5.8	—	—
190′	97.0	3.0	—	—
120′	95.0	5.0	—	—
120′	96.7	3.3	—	—
120′	92.8	7.2	—	—
70′	96.9	3.1	—	—
70′	91.2	8.8	—	—
65′	96.5	3.5	—	—
59′	95.3	4.7	—	—
53′	91.15	6.72	Organic 1.33	.22
47′	96.0	4.0	—	—
42′	96.7	3.3	—	—
36′	95.1	4.9	—	—
30′	96.8	3.2	—	—
24′	96.6	3.4	—	—
18′	96.7	3.3	—	—
12′	96.1	3.9	—	—
6′	96.2	3.7	.18	—

120′. *Second Terrace.* — A rock made up of rounded or angular fragments of coral, Halimeda, Orbitolites, etc. The matrix consists partly of "mud," but very largely of a deposit of radiating fibrous crystals of calcite, forming a concentric coating to the organic fragments. Any spaces left in the rock have been subsequently filled with a mosaic of calcite crystals.

200′. *Third Terrace.* — Section of a reef-forming coral (Figure 2) showing the spicular structure of the coral, the centers of calcification, and the thin mud-filled tubes of boring algæ, which here and there have penetrated the substance of the coral. One cavity in the coral is filled with "mud" containing small organic fragments, while another is seen to have entirely recrystallized. Lining the walls of the cavity the spicular character of the coral seems to have determined that prismatic crystals of aragonite should be formed in crystallographic continuity with the coral fibers. The remainder of the cavity is filled with a mosaic of calcite crystals except round the tubes of algæ, where long prismatic crystals, probably aragonite, have been formed.

70′. Section of rubble below Second Terrace. One half of the section represents a rock made of organic fragments, coated with a deposit of fibrous calcite, cemented together with a mosaic of calcite. This rock was planed down, and on the planed surface a layer of incrusting Polytrema grew, which has since recrystallized to clear calcite crystals. Above this the rock consists of a "mud," into which project from the surface of the Polytrema very large triangular-shaped crystals of calcite. The organisms include a radiolarian, two tunicate spicules enclosed by *Polytrema planum* and several perfect sections of Tinoporus.

65′. Section of a reef-forming coral, some of whose cavities are empty, some filled with "mud" altering to aragonite, some with aragonite optically continuous with the coral fibers, while others are filled with a mosaic of calcite crystals. The difference between aragonite and calcite is well seen after boiling with cobalt nitrate.

53′. A certain amount of incrusting fibrous calcite occurs, investing organic fragments. In some coral fragments aragonite has been formed, but most of the matrix and the material filling the cracks is calcite. The organisms include Halimeda, Lithothamnion, coral fragments and alcyonarian spicules, and a number of small rounded mud pellets suggest in appearance the excrement of fish.

18′. The matrix of the rock is chiefly "mud," but some has crystallized in the form of calcite. Aragonite organisms, such as Halimeda and corals, remain unaltered, and secondary aragonite partly fills some cavities in the coral.

15′. Largely made up of coral fragments with some Carpenteria, tunicate spicules and echinid spines. It was originally cemented by an investing layer of concentric fibrous calcite. Subsequent extensive solution has removed most of this layer and has in places dissolved part of the organisms.

C. The Tonga Group.

The Tonga, or Friendly Islands, consist of an elliptical ring of islands, of which the most important members are Eua, Tongatábu, and Vavau.

Eua. — The most southerly island of the Tonga Group is Eua, which is situated in latitude 21° 20′ S., longitude 174° 55′ W. The island rests on a volcanic base,[1] and consists largely of elevated limestone with vertical cliffs on the eastern face, some of which are over 1000 feet in height. At all projecting parts are lines of terraces; at the north three are visible, at the south five, and traces of a sixth. The island is composed of two ridges [2] running north and south, and separated by a deep valley. The western ridge is 500 feet in height, the eastern one 1000 feet or more.

Chemical. — A specimen collected from the slopes of the central valley at 600 feet contained 7.7 per cent of magnesium carbonate, while another from the second terrace at 250 feet yielded only 4.5 per cent. The third specimen was from the first terrace at 120 feet, and was found to be highly dolomitic, containing no less than 40.4 per cent of magnesium carbonate.

Height.	Calcium Carbonate.	Magnesium Carbonate.
600′	92.3	7.7
250′	95.5	4.5
120′	59.6	40.4

Microscopical. 600′. — A crystallized "coral sand" and "mud" from the central valley of the island. One coral present shows its original structure, but the rest are represented by "ghosts," consisting of a dirt line surrounding clear calcite. The matrix is partly "mud," partly granular calcite.

250′. *Second Terrace.* — Fragments of Globigerina, Carpenteria, Halimeda, etc., are set in dark "mud." The aragonite organisms such as Halimeda are recrystallized, as are some of the calcite forms such as Globigerina. Carpenteria, however, retains its fresh brown appearance.

120′. *First Terrace.* — This appears to have been a coral "mud" which has been dolomitized. Some of the organisms such as Carpenteria and alcyonarian spicules remain apparently unaltered. The arrangement of the crystals round some cavities suggests deposition from solution.

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[1] Notes on the Geology of the Tonga Islands, J. J. Lister, Q. J. G. S., Vol. XLVII., pp. 590–616.

[2] American Journal of Science, 1900, p. 193; Mem. Mus. Comp. Zoöl., 1902, XXVI., No. 1, p. 37.

Tongatábu. — Tongatábu is an irregular crescent-shaped island 22 miles long, situated in latitude 21° 10′ S., longitude 175° 10′ W.[1] The cliffs on the south coast rise to a height of 250 feet, and then fall towards the north coast to 10 or 20 feet. Round the coast three terraces are seen, and the interior is partly occupied by a shallow lagoon.

Chemical. — The only limestone examined was from Mount Sion Hill, at a height of 50 feet, and contained only 2.3 per cent of magnesium carbonate.

Height.	Calcium Carbonate.	Magnesium Carbonate.
50′	97.7	2.3

Microscopical. — The matrix of the rock consists of "mud." Cavities in the rock are lined with calcite crystals, and the organisms are to a large extent represented by calcite infillings.

Vavau. — At the northern end of the Tonga Group the elliptical plateau of Vavau[2] occurs in association with a number of smaller islets. Three or four limestone terraces are seen at levels of 140, 260–350, and 420–520 feet respectively. The northern edge of Vavau rises to well over 500 feet, and slopes down inland and to the south.

Chemical. — Limestones from the third, second, and first terraces exhibited a close similarity in composition; in each case only about 3 per cent of magnesium carbonate was found.

	Height.	Calcium Carbonate.	Magnesium Carbonate.	Insoluble Residue.
3d Terrace	Highest Point	97.4	2.6	
	360′	97.0	3.0	.03
2nd Terrace	350′	97.4	2.6	
	310′	96.8	3.2	
1st Terrace	140′	97.2	2.8	

Microscopical. Highest point, north shore. — The section is entirely filled by an alcyonarian showing spicules whose cavities are lined with calcite.

360′. The rock is made up of organisms and organic fragments, lined with an investing layer of fibrous calcite and cemented into a compact rock with a clear mosaic of calcite crystals. The organisms comprise coral fragments, Polytrema, Lithothamnion, and much-altered Halimeda.

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[1] American Journal of Science, 1900, p. 193; Mem. Mus. Comp. Zoöl., 1902, Vol. XXVI., No. 1, p. 32.

[2] American Journal of Science, 1900, p. 193; Mem. Mus. Comp. Zoöl., 1902, Vol. XXVI. No. 1, p. 33.

350′. Similar to the rock from 360 feet, except that the concentric coating to the fragments is rather less prominent.

310′. Consists of Polytrema, coral fragments, Lithothamnion, Gypsina, etc., with a feebly marked concentric coating of fibrous calcite.

140′. *First Terrace.* — Gypsina and Carpenteria can be recognized, but all the aragonite organisms, including the corals, have recrystallized to clear calcite. The matrix consists mostly of "mud," and no fibrous calcite surrounds the organisms.

D. The Paumotus Group.

The islands of this group are described by Mr. Agassiz, in connection with the explorations of the "Albatross."[1] He finds that the western part of the Paumotus consists of a partly submerged ledge of older coralliferous limestone covered with a thin modern reef. The land of the Paumotus atolls is built up simultaneously by accumulations of sand both from the lagoon side and also from the sea face. Mr. Agassiz regards this circumstance as characteristic of the group.

MAKATEA (called also Mehetia, Metia, or Aurora Island) is situated in latitude 17° 45′ S., longitude 148° 3′ W., and consists of upraised coralliferous limestone. The greatest elevation is 230 feet, and a central depression exists 50 feet lower than the rim of either face. At the western end of the island four terraces can be traced.

Chemical. — This island gained geological importance owing to the visit of Prof. J. D. Dana, and the fact that the first specimen of dolomitized coral limestone was collected by him from this locality. The specimens from the terraces and central basin, which I have analyzed, show, however, practically no dolomitization, as the percentage of magnesium carbonate in the rocks does not rise above 3.7. This result is interesting as illustrating the partial character of the dolomitization which this island, in common with many others, has undergone.

	Height.	Calcium Carbonate.	Magnesium Carbonate.	Insoluble Residue.
3rd Terrace		96.5	3.5	
"	200′	97.2	2.8	
"	200′	96.5	3.5	
2nd Terrace		96.5	3.3	.20
Basin	150′	96.3	3.7	

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[1] American Journal of Science, 1900, pp. 34–43; Mem. Mus. Comp. Zoöl., 1902, Vol. XXVI. No. 1, p. 18.

Microscopical. 200′. *Third Terrace.* — Figure 4. The slide shows a transverse section of a compound coral whose stereoplasm has been changed to granular crystals of calcite and whose inner and outer walls are now marked by dirt lines. Some of these calcite crystals are clear, but many have an inner kernel of opaque material often roughly parallel to the external boundary of the crystal. This apparent zoning is quite an uncommon feature of calcite in rock sections. Cavities between the septa of the coral and between adjacent organisms have been filled with "mud," which has subsequently crystallized in the form of a muddy mosaic of calcite.

150′. *Basin.* — The rock is largely made up of unaltered Polytrema and other fragments, which have been changed to clear calcite. The matrix of the rock consists of "mud," in which cavities occur lined with scalenohedral crystals of calcite (Figure 5). In one or two of these cavities the scalenohedra are seen to be zoned.

Niau. — Niau or Greig Island lies in latitude 16° 10′ S., longitude 146° 20′ W., and is the only atoll in the Paumotus, visited by Mr. Agassiz,[1] in which the lagoon is entirely shut off from the sea. The ledge of older limestone forms a rim surrounding the circular lagoon, and is ⅓ mile wide and 15–20 feet high.

Chemical. — Two specimens were analyzed, both from a height of 20 feet, and were found to be limestones containing 5.0 and 2.7 per cent respectively of magnesium carbonate.

Height.	Calcium Carbonate.	Magnesium Carbonate.
20′	95.0	5.0
20′	97.3	2.7

Microscopical. 20′. — The specimen was collected halfway across the rim of the island, and consists of a section of a large coral with smaller coral fragments. The coral is very fresh, being brown in color, and in places show the centers of calcification very clearly. Some spaces in the coral are filled with "mud" to a certain level, forming horizontal "mud floors," and subsequently scalenohedral crystals of calcite were deposited from solution upon the surfaces of the "mud floors" and also lining the coral walls.

E. The Ladrones.

Guam. — This island is situated in latitude 13° 30′ S., longitude 145° E. It is mainly volcanic in origin, but the northern half consists of elevated coralliferous limestone with vertical cliffs 100–300 feet in height.

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[1] American Journal of Science, 1900, pp. 369–374.

The massif at the southern half of the island is volcanic, and the highest ridge reaches 1000 feet.

Chemical. — Four rocks were analyzed, and were found to contain very little magnesium carbonate, the amounts varying from 1.6 to 3.4 per cent.

	Height.	Calcium Carbonate.	Magnesium Carbonate.	Insoluble Residue.
Summit of Mount Makama		97.2	2.8	
South side of Apra		96.8	3.4	
	400′	96.5	1.6	1.94
	20′	97.0	3.0	

Microscopical. Summit of Mount Makama. — The matrix of the rock consists of "mud," part of which has been converted into calcite. Many small ellipsoidal fragments occur in the rock, and their shape and size suggest that they may have passed through the bodies of fish.

2. Indian Ocean.

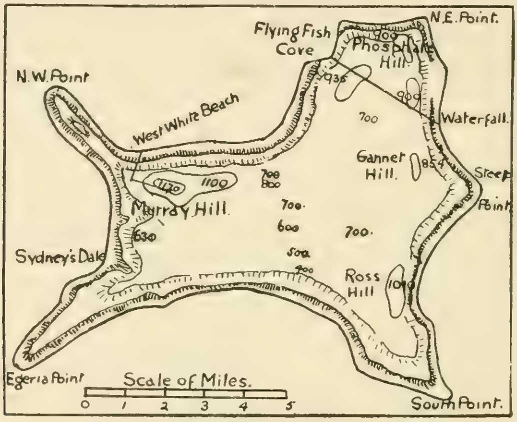
Christmas Island.

Dr. Andrews has described the structure of the island in detail in his monograph published in 1900 by the Trustees of the Natural History Museum. It will, therefore, not be necessary for me to do more than briefly summarize the chief points in his description. The island lies in the eastern part of the Indian Ocean, in latitude 10° 25′ S., longitude 105° 42′ E., 190 miles south of Java, and 550 miles northeast of Keeling Cocos atoll. The greatest length of the island is 12 miles, the greatest breadth 9 miles, and the total area about 43 square miles. The accompanying map is drawn on a reduced scale from the one published in the monograph. Upon it are marked the localities and lines from which Dr. Andrews obtained the limestones which form part of the subject-matter of this inquiry. The specimens were collected in vertical sequence from the cliffs and slopes, and their heights were carefully noted either by measurement or by the use of an aneroid barometer.

The basis of the island is almost certainly a volcanic peak, upon whose summit and flanks accumulations of tertiary limestones have been deposited. Eruptions, probably submarine, took place from time to time, and the products of eruption were interstratified with the limestones. The earlier eruptive rocks were first trachyte, then basalt, while the latest consisted of beds of palagonite tuff, upon which the great mass of the Miocene (Orbitoidal) limestone rests.

The greater part of the exposed surface of the island consists of a plateau at a general level of about 600–700 feet. Higher ground is found to the north at Phosphate Hill, which exceeds 900 feet in height, while the highest ground in the island occurs at Murray Hill on the west, where the altitude reaches 1170 feet. During the period of elevation of the central nucleus there were several pauses, as a result of which fringing reefs occur at various levels. These are now represented by a series of four slopes, or inland cliffs, continuous nearly all round the island.

1. The newest or present fringing reef.
2. The shore terrace, 50 feet in height.
3. The first inland cliff, from 80–300 feet in height.
4. The second inland cliff, ranging from 320–600 feet in height.


N.E. Point.
Flying Fish Cove
Phosphate Hill.
900
936
N.W. Point
West White Beach
909
700
Waterfall.
Gannet Hill.
854
Steep Point
1170
1100
700
800
Murray Hill.
700.
600
700.
630
Sydney's Dale
500
400
Ross Hill
1010
Egeria Point
Scale of Miles.
0
1
2
3
4
5
South Point.

Christmas Island.

Faulting and slipping have occurred fairly extensively, especially on the rim of the island, and it is largely owing to this cause that the terraces are not quite continuous. This is particularly the case on the northwest at Flying Fish Cove, where a fairly complete section is seen from the older Eocene and Oligocene limestones at the base up to the Miocene rocks at the top of the cliff. Specimens have been examined which illustrate sections both from the older rocks and also from the older and newer inland cliffs or fringing reefs. The results of the examination of these rocks will now be given in the order mentioned.

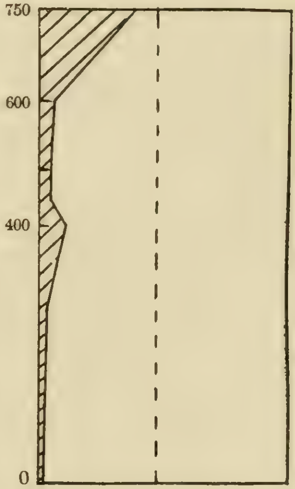
Older Rocks (*Eocene to Miocene*).

Flying Fish Cove. *Chemical.* — At this part of the island a good section occurs in the sea cliff. Rocks of Eocene or Oligocene age are exposed at the sea level, while on the plateau above, corals occur to which a Miocene age has been assigned. The continuity of the limestones is broken by two fairly thick beds of basalt, both probably of submarine origin. The beds of basalt are separated by a considerable thickness of a middle yellow limestone, probably of Oligocene or lower Miocene age. The specimens analyzed from the sea cliff at Flying Fish Cove were collected at definite heights from the sea-level up to 750 feet, both from the north and south ends of the Cove. Of these, the uppermost rock, No. 664, from a height of 750 feet, contains 36.2 per cent of magnesium carbonate. All the rest are limestones, most of which contain only from 3 to 4 per cent of that compound, with the exception of No. 595, in which 8 per cent is present. Insoluble matter is almost unrepresented in the higher rocks, — No. 549 contains .03 per cent, — but the three oldest limestones have from .7 to .8 per cent of insoluble residue. This circumstance is probably due to their close association with the two beds of basalt which occur in this part of the island.

Number.	Height.	Calcium Carbonate.	Magnesium Carbonate.	Insoluble Residue.
664	750′	63.8	36.2	—
991	600′	95.7	4.3	—
827	550′	94.6	5.4	—
521	530′	96.1	3.9	—
963	500′	97.29	2.71	—
549	500′	96.8	3.4	.03
571	480′	97.0	3.0	—
845	450′	97.4	2.6	—
595	400′	91.2	8.0	.80
840	275′	96.8	2.5	.70
2	0′	96.7	2.6	.72

FLYING FISH COVE.

OLDER ROCKS.



Microscopical. No. 521. — An orbitoidal limestone containing Carpenteria, Orbitolites, Lithothamnion, and the cast of a coral in "mud." Much of the section consists of "mud," but some has altered to clear calcite, and in this part the organisms are represented by dirt lines.

No. 963. The organic fragments in this limestone are quite fresh, and consist of Carpenteria, *Polytrema miniaceum*, Amphistegina, alcyonarian spicules, echinid spines, and Lithothamnion. The organisms are for the most part invested with a coating of fibrous muddy calcite, and the remaining spaces have been filled with a mosaic of clear calcite crystals.

No. 549. An orbitoidal limestone having a matrix of calcite. An incrusting deposit of calcite partially fills some cavities and cracks occurring in the rock.

No. 571. An orbitoidal limestone similar to the last, but containing more "mud" in the matrix. Some of the organisms have been altered to a brownish silt. Acute crystals of calcite project from their margins, and adjoining fragments have been cemented subsequently by large crystals of calcite.

No. 845. A Lithothamnion limestone in which many of the organisms are represented by pseudomorphs in calcite.

No. 595. Globigerina and small fragments of Carpenteria are abundant in this limestone, while calcite crystals fill cracks in the rock, and serve to cement numerous fragments of yellow palagonite.

No. 840. A limestone containing Gypsina, Halimeda (?), and echinid spines. Minute volcanic fragments are scattered through the rock, which is rather cavernous.

No. 2. An orbitoidal limestone containing, in addition, well-preserved Gypsina, Amphistegina, and Lithothamnion.

ABOVE FLYING FISH COVE. *Chemical.* — Proceeding inland from No. 664 at the top of the sea cliff, the level falls slightly at first, and three specimens collected along this gentle slope have been analyzed. No. 663 is from about the same level as No. 664 — namely, 750 feet — but is found to contain only 1.7 per cent of magnesium carbonate, while a little further inland, from a level of 710 feet (No. 657), yields 25 per cent. Quite close to this last limestone the surface of the ground is covered with a chalk-like deposit in which occur harder nodules. The centers of these nodules, represented by No. 658 A, consist of a compact limestone containing only 2 to 3 per cent of magnesium carbonate, while the soft crumbling exterior (No. 658 B) is highly dolomitic, containing no less than 39.5 per cent of magnesium carbonate. The association of these two rocks is very interesting, and would seem to suggest that the dolomitic rock may, in this case, arise by the concentration of magnesium carbonate, owing to the superior solubility of calcium carbonate in percolating water containing atmospheric carbon dioxide. Further back from the sea cliff the ground rises rather sharply to a height of 880 feet, and an analysis made at that level (No. 514) yields 40.67 per cent of magnesium carbonate, while some distance to the south-west (No. 1011), at a height of 800 feet, is also dolomitic containing 35.2 per cent of magnesium carbonate.

Number.	Height.	Calcium Carbonate.	Magnesium Carbonate.
663	750′	98.3	1.7
657	710′	97.5	2.5
658 A	710′	97.5	2.5
658 B	710′	60.5	39.5
514	880′	59.33	40.67
1011	800′	64.8	35.2

Microscopical. No. 658 A. — The rock consists of small fragments of well-preserved organisms, such as Carpenteria, Lithothamnion, etc., set in a gray silty calcite matrix. The rock is probably a recrystallized calcareous "mud."

No. 658 B. The slide consists almost entirely of idiomorphic crystals of dolomite, having dark centers. Most of the organisms have been obliterated, but one or two specimens of Amphistegina, and possibly Polytrema, occur. In some places scalenohedral crystals project from the surfaces of organic fragments.

No. 514. The section consists largely of rhombohedra of dolomite, in many of whose centers are dark materials caught up in an early stage of crystallization, and hence giving the appearance of zoning. All organisms have disappeared, except possibly where a meandrine arrangement of opaque or silty matter may represent a former organism, such as coral or Polytrema.

No. 1011. A dolomitic limestone in which many of the crystals have dark centers. Some spaces in the rock have, since dolomitization, been filled with secondary calcite.

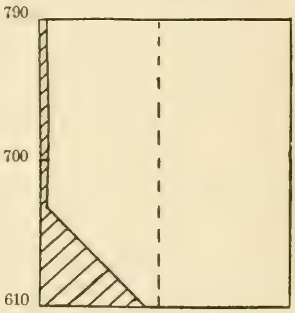
SOUTHEAST OF PHOSPHATE HILL. — The section of the older rocks at this spot is not complete. The upper 200 feet is clear, and at one place near the shore, erosion has caused the Eocene or Oligocene limestones to be exposed below a bed of basalt. Between these points three terraces or fringing reefs occur, and mask the older rocks. The average slope of the cliffs towards the sea is about 30°.

Chemical. — Miocene rocks are exposed from the top of the cliff at 790 feet down to 610 feet. Analyses made between these heights show that the upper 120 feet consists entirely of limestones, with about 3 per cent of magnesium carbonate. At the level of 640 feet the percentage has increased to 27.7, while at 610 feet no less than 42.7 per cent of magnesium carbonate is found. At this point the section of the older rocks is masked by terraces or fringing reefs, which form a cloak of newer material, only pierced at one point above sea-level, where an Eocene or Oligocene limestone occurs (No. 635) having 3.9 per cent of magnesium carbonate.

Number.	Height.	Calcium Carbonate.	Magnesium Carbonate.
610	790′	97.0	3.0
611	760′	97.3	2.7
612	730′	96.8	3.2
613	700′	97.1	2.9
614	670′	97.7	2.3
615	640′	72.3	27.7
616	610′	57.3	42.7
635	0′	96.1	3.9

SOUTH-EAST OF PHOSPHATE HILL.

Older Rocks.



Microscopical. No. 610. — A limestone containing an unrolled fragment of Orbitoides, together with Polytrema, Amphistegina, and a little yellow isotropic material, possibly palagonite. The organisms are well preserved, the rock is cavernous, and the semi-opaque matrix is seen under the high power to be crystalline.

No. 615. A very cavernous dolomite showing no traces of organisms, except a few meandrine forms. The spaces and cavities in the rock have been, to a great extent, filled with large slightly yellow crystals of secondary calcite.

No. 616. A uniform, compact, fine-grained dolomite, showing a few small fragments of Lithothamnion, and here and there dark meandrine patches suggesting the former presence of Polytrema.

Sydney's Dale. — This dale is a gorge on the west coast, originally determined by a fault line, and further excavated by a stream which runs through it. In this dale Oligocene or Eocene beds occur, containing the oldest type of Orbitoides met with at Flying Fish Cove.

Chemical. — Three limestones were analyzed: No. 308, from a height of 350 feet, contains 39.22 per cent of magnesium carbonate, while No.

348 and No. 350, from heights of 325 and 310 feet, contain respectively only 2.6 and 5.2 per cent of that compound.

Number.	Height.	Calcium Carbonate.	Magnesium Carbonate.	Calcium Phosphate.
308	350′	60.63	39.22	.15
348	325′	97.4	2.6	
350	310′	94.8	5.2	

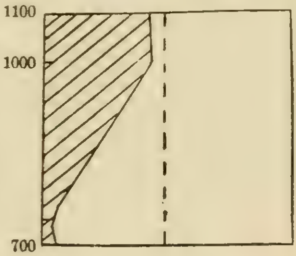
Microscopical. No. 348. — A rather cavernous limestone, largely consisting of crystalline semi-opaque cement, and in which Globigerina occurs rather plentifully.

Rocks from the Interior of the Island (Miocene ?).

LINE ON THE ROAD TO MURRAY HILL. — This road starts from a point where it meets another road at right angles to it running down to West White Beach. The limestones were collected in vertical sequence up the slope, from 650 feet to 1100 feet, almost at the summit of Murray Hill.

Number.	Height.	Calcium Carbonate.	Magnesium Carbonate.
378	1100′	60.34	40.02
379	1000′	59.8	40.2
360	725′	96.0	4.0
356	690′	97.1	2.9
355	650′	95.7	4.3

MURRAY HILL.



Chemical. — The two highest specimens, No. 378 and No. 379, from heights of 1100 and 1000 feet respectively, contain about 40 per cent of magnesium carbonate, but the remaining three specimens are limestones, in which the amount does not reach 5 per cent.

Microscopical. No. 378. — Lithothamnion can still be recognized, and a gray meandrine dolomitic "silt" suggests the former presence of corals. The amount of finely crystalline dolomite is very large, but cavities are lined with clear rhombohedra, and no zoning is seen.

No. 360. Almost entirely composed of very small rounded or fusiform fragments, with a few larger rounded pieces, cemented by clear scalenohedral crystals of calcite. The appearance of these fragments suggests that they may represent the excrement of fishes, and this idea is supported by their general uniformity of size and fusiform shape.

Cliffs over West White Beach. — These limestones, only two in number, are from the road leading down to West White Beach. This road is joined at right angles by the road to Murray Hill.

Chemical. — Two analyses were made of rocks from 700 and 600 feet, and these contained 14.3 and 3.3 per cent of magnesium carbonate respectively.

Number.	Height.	Calcium Carbonate.	Magnesium Carbonate.
365	700′	85.7	14.3
373	600′	96.7	3.3

Microscopical. No. 365. — The rock is made up of fragments of organisms which for the most part are well preserved. The aragonite organism Halimeda has been, however, changed to calcite and the cavities in the rock are filled with the same mineral.

Phosphate Hill Road. — This road starts just below the 800 feet contour inland from Flying Fish Cove, and at this point is joined by a road going south-east from Flying Fish Cove to the Waterfall. It proceeds to Phosphate Hill along gently rising ground.

Chemical. — The highest specimen, No. 815, contains 13 per cent of magnesium carbonate. Twenty feet lower, No. 816 yields 7.4 per cent, and No. 817, from a height of 780 feet, contains only 3 per cent of magnesium carbonate.

Number.	Height.	Calcium Carbonate.	Magnesium Carbonate.
815	820′	87.0	13.0
816	800′	92.6	7.4
817	780′	97.0	3.0

Microscopical. No. 815. — A rock made up of large opaque fragments set in a semi-opaque matrix. Amphistegina is common, and the organisms as a whole appear to be unaltered.

Southeast Road between Flying Fish Cove and the Waterfall. — This road starts from a point at 700 feet above Flying Fish Cove. It then rises to 900 feet, falling to 820 feet, again rising to 900 feet and falling to the south-east towards the Waterfall. Specimens, from No. 709 to No. 700, were collected along this road.

Chemical. — One limestone, No. 707, from the first slope nearest Flying Fish Cove, is dolomitic, but the remaining nine specimens, collected at intervals along the road, do not contain more than about 5 per cent of magnesium carbonate.

Microscopical. No. 708. — A meandrine cast of a coral in calcite and sections of *Polytrema planum* fill most of the slide. The semi-opaque matrix is seen under the high power to consist of calcite crystals.

Number.	Height.	Calcium Carbonate.	Magnesium Carbonate.
709	700′	94.8	5.2
708	700′	95.1	4.9
707	880′	66.4	33.6
706	900′	95.0	5.0
705	900′	94.9	5.1
704	870′	95.9	4.1
703	820′	95.3	4.7
702	870′	96.8	3.2
701	900′	96.7	3.3
700	790′	96.0	4.0

No. 705. A section of a fragmental limestone containing perfectly fresh-looking and unrolled *Orbitoides neo-dispansa*, besides Polytrema Amphistegina, Orbitolites, Carpenteria, Lithothamnion, set in a matrix of calcite.

Isolated Analyses from the Interior of the Island.

Vicinity of Phosphate Hill. — Three specimens were collected from the slopes of the hill just below the bed of phosphate which forms the capping to the summit. All three specimens are dolomitic, but it is an interesting circumstance, considering their relation to the phosphatic capping, that none of them give any appreciable reaction for phosphate with ammonium molybdate.

Chemical.

Number.	Height.	Calcium Carbonate.	Magnesium Carbonate.
800	850′	65.05	34.77
804		67.88	31.96
811		61.79	37.96

Microscopical. No. 800. Figure 7. — A dolomitic limestone in which the matrix consists of crystals of dolomite. Most of the organisms are coated with minute acute crystals, probably calcite. The echinid spines and some of the sections of Amphistegina appear almost unaltered, but many of the organisms have partially recrystallized, and rhombs of dolomite have invaded the organisms from without inwards. This is well seen in several longitudinal and transverse sections of Lithothamnion, while a Halimeda has some of its tubules unaltered, but in others rhombs of dolomite have been formed, and destroyed the boundary of the walls of the tubules. A cavity in the rock has been filled with clear crystals of dolomite, while zoning by included muddy material is well seen in those crystals formed by the recrystallization of Lithothamnion.

No. 811. A dolomitic limestone, with a fair quantity of semi-opaque material. Much of the slide, however, consists of rhombohedra of dolomite, with dark centers parallel to the outside boundary, and representing "silt" caught up during recrystallization. Cavities are numerous, and the walls of these are lined with clear crystals of dolomite.

East Coast. — One specimen has been analyzed from the summit of the upper cliff on the East Coast at a height of 800 feet.

Chemical. — It is a limestone containing only 2.44 per cent of magnesium carbonate and .15 per cent of calcium phosphate.

Number.	Height.	Calcium Carbonate.	Magnesium Carbonate.	Calcium Phosphate.
134	800′	97.56	2.44	.15

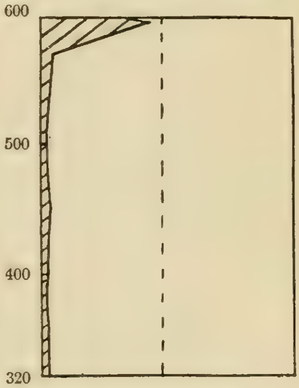
Microscopical. No. 134. — This is a limestone containing many sections of *Polytrema planum*, while Lithothamnion also occurs. Semi-opaque material is present in the matrix, while clear calcite fills some of the cavities.

Second Inland Cliffs (Older fringing Reefs — Lower Pliocene ?).

Southeast of Phosphate Hill. — This is one of the fringing reefs which partly mask the older rocks in this section. It occurs between the levels of 600 and 300 feet.

Chemical. — No. 617 occurs on the subhorizontal flat marking the top of the reef or cliff, and contains 34.1 per cent of magnesium carbonate. No. 618 was found at the outer edge of the flat at the top of the cliff, and on analysis yields no less than 43.30 per cent of magnesium carbonate. This is the most highly dolomitized of any of the limestones which have been analyzed. It is possible that both these rocks may be derived from the older dolomitic limestones occurring in the cliff above. The remainder of the analyses in this section are those of limestones, in which the amount of magnesium carbonate does not rise above 4 per cent.

Number.	Height.	Calcium Carbonate.	Magnesium Carbonate.	Insoluble Residue.
617	600′	65.9	34.1	—
618	600′	56.82	43.30	—
619	570′	97.6	2.4	—
620	540′	96.3	3.7	—
621	510′	96.8	3.2	—
622	480′	97.1	2.9	—
623	450′	96.1	3.9	—
624	420′	96.3	3.7	—
625	390′	97.5	2.5	.024
626	360′	96.6	3.4	—
627	320′	96.0	4.0	—



SOUTH-EAST
OF PHOSPHATE HILL.

Second Inland Cliff.

Microscopical. No. 618. — A cavernous rock, containing hollow casts of Amphistegina. The only recognizable organism is a much altered Lithothamnion. The matrix consists chiefly of clear rhombohedral crystals of dolomite, a few of which show zoning by included material.

No. 619. This appears to be a rubble rock. Small fragments of what looks like a dolomitic limestone are mixed with other darker limestone fragments. One small rounded augite is present, while in one of the fragments a piece of coral occurs, having its organic structure well preserved.

No. 623. A very close-grained compact limestone, containing a few rhombohedral crystals. Very few recognizable organisms are present in this rock.

West White Beach. — This fringing reef forms a shallow cliff between the levels of 500 and 400 feet at West White Beach, about a mile northwest of Murray Hill.

Chemical. — Four analyses were made, and the rocks were found to be limestones, containing only a minute quantity of insoluble material, and from 2.6 to 5.8 per cent of magnesium carbonate.

Number.	Height.	Calcium Carbonate.	Magnesium Carbonate.	Insoluble Residue.
354	500′	94.3	5.7	.024
374	500′	94.2	5.8	
304	470′	95.5	4.5	.024
368	440′	97.4	2.6	

North-east Point. — A specimen from the summit, at height of 600 feet, yielded 1.72 per cent of magnesium carbonate, and .2 per cent of calcium phosphate.

Number.	Height.	Calcium Carbonate.	Magnesium Carbonate.	Calcium Phosphate.
179	600′	91.72	1.72	.20

Microscopical. — A limestone, with a matrix largely of silt, containing unaltered Lithothamnion, Carpenteria, Polytrema, Truncatulina, and Amphistegina. Cracks in the rock have been filled with a mosaic of secondary calcite, while some cavities are lined with scalenohedral crystals.

First Inland Cliff (*Newer fringing Reef. Late Pliocene ?*).

North of Flying Fish Cove. — At Flying Fish Cove the fringing reefs are not represented, but a little to the north the shore cliff is found, and also the first inland cliff, which forms a well-marked feature between the heights of about 60 and 300 feet.

Chemical. — All the rocks analyzed from this cliff are limestones, but at levels of 250 feet (No. 211), 200 feet (No. 208), and 50–60 feet (No. 200) the amount of magnesium carbonate present rises to 10.9, 8.5, and 10.5 per cent respectively. In the remaining limestones the amount varies from 2 to 4 per cent.

Microscopical. No. 1032. — A rock composed of fragments from the reef. Calcareous algæ, Polytrema, and echinid spines occur, but a large part of the slide is occupied by a section of a compound coral, whose organic structure is well preserved. Crystals of aragonite are in optical continuity with the coral fibers, and wholly or partly fill the interstices. The residual space is filled with a clear mosaic of calcite, which looks as if it has arisen largely at the expense of the aragonite. In some parts of the slide organic fragments are invested with a coating of fibrous calcite crystals. Some of the organisms are represented only by dirt lines round the margins of the organisms, the interior being recrystallized calcite.

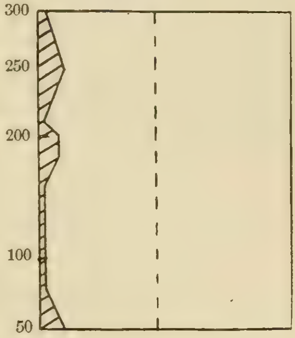
No. 211. Most of the slide is occupied by the section of a coral, whose spaces are filled partly with "mud," partly with aragonite crystals continuous with the coral fibers, and partly with clear calcite.

No. 209. Large coral fragments and other organisms make up the bulk of the rock, and are cemented together by a deposit of fibrous calcite crystals.

Number.	Height.	Calcium Carbonate.	Magnesium Carbonate.	Insoluble Residue.
1032A	300′	97.7	2.3	—
1032	300′	95.8	4.2	—
211	250′	89.1	10.9	—
209	210′	96.9	3.1	—
208	200′	91.5	8.5	.024
206	160′	97.3	2.7	—
203	90′	98.0	2.0	—
201	80′	97.1	2.9	—
200	50–60′	89.5	10.5	—

NORTH OF FLYING FISH COVE.

First Inland Cliff.



No. 208. Coral fragments, sections of lamellibranchs, and other organisms, including several specimens of Globigerina, are set in a matrix of dark calcareous "mud." In one part of the slide fibrous calcite invests the organisms.

No. 202. A limestone with a muddy matrix, containing coral fragments and many specimens of Globigerina. Muddy, fibrous incrusting crystals of calcite invest some fragments.

No. 200. A limestone, largely composed of coral fragments, with aragonite crystals in some cavities. A large amount of fibrous cementing calcite occurs. Round Lithothamnion, scalenohedral crystals were first formed, and then an outer layer of fibrous calcite, while a plate of calcite has surrounded an echinid spine, the deposited material being in optical continuity with the calcite of the organism.

South-east of Phosphate Hill. — Below the second inland cliff another cliff occurs between the heights of 200 and 300 feet, which forms the newer fringing reef in this part of the island.

Chemical. — Two analyses only have been made. Both the rocks are limestones, and contain 2.3 and 3.0 per cent of magnesium carbonate respectively.

Number.	Height.	Calcium Carbonate.	Magnesium Carbonate.	Insoluble Residue.
630	270′	97.0	3.0	.074
631	220′	97.7	2.3	

Microscopical. No. 630. — A somewhat cavernous limestone, whose matrix consists of calcite. A fair number of rhombohedral crystals occur, some of which have dark centers. The organic fragments are small and badly preserved, and are represented by an interior of calcite with dirt lines round the external margins of the organisms.

East Coast. — Steep Point. — The reef here makes a vertical cliff between the levels of 200 and 300 feet.

Chemical. — All the rocks are limestones with magnesium carbonate in amounts varying from 2.2 to 6.7 per cent.

Number.	Height.	Calcium Carbonate.	Magnesium Carbonate.	Insoluble Residue.
1010	300′	96.9	3.1	—
1009	290′	93.3	6.7	—
1008	275′	95.8	4.2	—
1007	260′	95.5	4.5	—
1006	250′	95.4	4.6	—
1004	230′	96.8	3.2	.026
1003	215′	97.8	2.2	—
1002	200′	95.0	5.0	—
1001	200′	97.1	2.9	—

Microscopical. No. 1006. — A fragmental rock made up of pieces of older rocks containing fragments of corals and of Orbitoides. These fragments are cemented with a matrix first of fibrous calcite, the consolidation being completed with a granular mosaic of calcite crystals.

No. 1005. A limestone containing much opaque "mud," in which casts of simple corals are preserved. Carpenteria is abundant in this rock.

West White Beach. — The rocks here form a low cliff between the heights of 250 and 380 feet.

Chemical. — Three analyses show that magnesium carbonate is present in amounts varying from 2.1 to 5.7 per cent, while the fourth limestone from 300 feet contains 11.2 per cent of magnesium carbonate.

Number.	Height.	Calcium Carbonate.	Magnesium Carbonate.	Insoluble Residue.
303	375′	95.5	4.5	
372	300′	88.8	11.2	
305	280′	94.3	5.7	.04
371	250′	97.9	2.1	

Microscopical. No. 372. Figure III. — A fragmental limestone containing corals, gastropods, echinid spines, Orbitolites, Lithothamnion, and Halimeda. The coral has aragonite crystals in optical continuity with its own fibers, while scalenohedra incrust the Lithothamnion. All the organisms are cemented with fibrous calcite radiating from each organism, and interfering with the deposit from an adjacent fragment, so as to produce a polygonal effect in the rock section.

South End of East Coast. *Chemical.* — One analysis from a height of 400 feet yields 16.9 per cent of magnesium carbonate.

Number.	Height.	Calcium Carbonate.	Magnesium Carbonate.
131	400′	83.1	16.9

Microscopical. — A dolomitic limestone whose matrix consists largely of rhombohedral crystals with cavernous spaces. The organisms consist almost entirely of *Polytrema miniaceum.*

III. Chemical Summary.

In attempting to summarize the chemical results obtained from a study of limestones from fifteen raised coral islands, it is found that the facts group themselves most naturally round three points. These are: — (A) The distribution of magnesium carbonate in the limestones, (B) the amount of calcium phosphate they contain, and (C) the extent to which insoluble residue is associated with them.

A. Chemical analysis shows that certain of the islands have been dolomitized from top to bottom. Ngillingillah and Vatu Vara belong to this class. Only one limestone from Yathata has been analyzed, and one from Kambara, but both are found to be highly dolomitic. Examination of several islands fails to show any appreciable dolomitization.

Niue, Vavau, Tongatábu, Niau, Guam, and Makatea are of this type. In the case of Makatea (Metia), however, Dana and Silliman have recorded the occurrence of dolomitic limestone, and it is possible that an examination of other specimens may show that some of the islands mentioned do contain dolomitic rocks. Limestones containing little or no magnesium carbonate are found associated with dolomitic limestones in Christmas Island, Mango, Namuka, and Eua.

On examining rocks from these islands it is found that dolomitization may occur at several horizons. In Namuka, the lowest and oldest rock is dolomitized, while in Christmas Island one of the Oligocene or Eocene rocks of Sydney's Dale, from a height of 350 feet, is highly dolomitic. Again, at Christmas Island, in the cliff section, east of Phosphate Hill, dolomite occurs in the Miocene rocks at a level of 600–640 feet. At Mango, limestones are only found at three heights, 370, and 310, and 298 feet; all the remaining specimens being highly dolomitic. Perhaps the occurrence of dolomite is most usual at the highest points of the islands. This is found to be particularly true of Christmas Island, where the three highest hills are all dolomitized, as are the tops of Mango, Ngillingillah, and Vatu Vara, while dolomitic limestones are found near to the summits of Yathata and Kambara.

Very little magnesium carbonate is, as a rule, found in the limestones from the newer reefs fringing the raised coral islands. In certain cases as much as 10 or 11 per cent of magnesium carbonate is found without the formation of recognizable crystals of dolomite, but in only two instances have highly dolomitic limestones been found among the rocks of the inland cliffs or terraces. At Christmas Island, the top part of the upper inland cliff south-east of Phosphate Hill is found to be highly dolomitic, while the other example is from the first inland cliff or terrace of the island of Eua. But in these cases it is difficult to say with certainty whether the rocks belong to a true fringing reef, a ledge in the older rocks cut back by the sea during a pause in elevation, or a submarine talus composed of the débris of the older rocks above it.

Many of the dolomitic limestones, in composition, approach to, and even slightly exceed, 40 per cent of magnesium carbonate. But it is an interesting circumstance that, up to the present, no rock having the composition of a true dolomite has yet been met with among the limestones from coral islands. The maximum value for magnesium carbonate yet recorded is 43.3 per cent, from one of the Christmas Island rocks.

B. More or less extensive deposits of guano are found here and there among the coral islands of the Pacific. At Christmas Island, the summits of Murray, Phosphate, and Ross Hills, according to Dr. C. W. Andrews, were low islands rising from the lagoon during Miopliocene times, and were covered with guano deposits. Percolating water has, since then, changed the subjacent limestone to almost pure calcium phosphate. At Phosphate Hill, the deposit is in places 10 feet thick, while at Murray Hill, a phosphate of aluminum and iron occurs, probably derived from the alteration of some volcanic rock. This seems to be comparable with Mr. Teall's description of the phosphatization of the trachyte of Clipperton Atoll.[1] Besides the massive deposits of phosphate, a small quantity occurs almost universally among all the limestones of coral islands. The amount has never been found to exceed .3 per cent, and is often much less. Its constant character is no doubt due to the small quantity which the organisms assimilate from the sea-water in building up their skeletons.

C. Organic residue is only found in the most recent and unaltered rocks, and is then present in amount up to 1.5 per cent. During the processes of consolidation and recrystallization of the rocks, the organic matter appears to be dissipated, probably to a great extent in the form of carbon-dioxide, and carried off by percolating water.

Insoluble inorganic residue is present in almost inappreciable amount in the very large majority of the rocks. As a rule, the insoluble residue varies from .01 to .20 per cent.

In a few of the limestones immediately associated with volcanic rocks such as occur in Christmas Island, Mango, and Guam, the amount of residue is larger, and in one case exceeds 4 per cent. This increase of insoluble matter is doubtless due to the proximity of the volcanic material. With the exceptions cited, the almost entire absence of inorganic residue is a marked feature of these oceanic coral islands. These facts seem to be significant, especially when it is considered that in deep-sea deposits, even in the neighborhood of coral islands, the amount of insoluble residue rarely falls below 1 per cent, and often rises to 20 per cent.[2]

In the case of the Singatoka cliffs, where the insoluble residue rises to nearly 2.5 per cent, the large amount is probably due to the formation of the limestone on the margin of the large island of Viti Levu, consisting almost entirely of igneous rocks.

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[1] Q. J. G. S., 1898, pp. 230–232.

[2] Report of Scientific Results of the Challenger Expedition, Appendix III., pp. 445–496.

Allowing for the disturbing effect in the proximity of volcanic rocks, it will be noticed that absence of insoluble residue may be regarded as characteristic of coral limestones formed in shallow water and under oceanic conditions, while deep-sea limestones and fringing reefs to great land masses normally contain upwards of 1 per cent of insoluble residue. It seems possible that these facts may be found to be of use in interpreting the mode of origin of some of the older limestones of the earth's crust.

The mineralogical and structural changes which take place in coral limestones are consequent upon certain chemical changes in the rocks, which may be briefly considered at this point. The formation of the investing fibrous deposit of calcite round organic fragments, noticed in rocks from some of the fringing reefs (Figure 3), is probably due to the coating of fragments with a deposit of calcium carbonate formed on a beach by the evaporation of sea-water on the recession of the tide. The carbon dioxide present in the water holds a certain amount of calcium carbonate in solution. This is precipitated when exposed to the air, owing to the evaporation of the water and the loss of carbon dioxide. A macroscopic study of the limestones also shows that a certain amount of solution must have taken place since the rocks have been upraised. It is noticed that many cavities in the limestones have been more or less filled with a stalagmitic coating of calcite, and in certain cases, with dolomite. These deposits are no doubt due to the solvent properties of rain water bearing carbon dioxide in solution, and the precipitation of the dissolved carbonates on the escape of the carbon dioxide. While subaerial changes such as these do undoubtedly occur, yet most of the chemical changes have probably taken place below the sea-level.

A study of the thin sections of the limestones shows that aragonite may arise from the alteration of calcareous mud, which fills certain cavities in the corals, while it is occasionally deposited in clear crystals directly from solution. Again, calcite may be formed by the alteration both of calcareous muds and of aragonite crystals, while under other circumstances it is found deposited directly from solution.

These processes require that the calcium carbonate shall first be dissolved in the sea-water, and, secondly, that under suitable conditions, it shall pass out of solution, and form a crystalline deposit. The solubility of calcium carbonate in sea-water is extremely small, and has been variously estimated at from 1 part in 10,000 to 1 part in 136,000. In all probability the solution is largely increased by the aid of carbon dioxide dissolved in the sea-water.

Messrs. Cornish and Kendall[1] have determined the relative solubility of aragonite and calcite organisms in water containing carbon dioxide, and their experiments show how readily aragonite organisms are disintegrated under these conditions.

The great abundance of animal life in and around coral reefs might help to supply the carbon dioxide, which would be augmented on the death and decay of both animals and plants. In some such way as this, calcium carbonate in the rocks of the reef may be dissolved, and the condition for the deposition of the dissolved carbonate is the local removal of the carbon dioxide. It is not easy to explain how this removal can be effected, but it is possibly due to the presence in large numbers of excessively minute algæ, whose absorption of carbon dioxide may help to bring about the precipitation of the calcium carbonate. As a rule, when calcium carbonate is deposited from cold water calcite alone is formed, while aragonite is deposited from hot solutions. But in coral limestones both calcite and aragonite are deposited from sea-water at the ordinary temperature, under suitable conditions. The physical and chemical properties of the organism on which the deposit is made, seem to have a determining influence on the particular form of calcium carbonate which is eventually formed.

With regard to the mechanism of the chemical change from calcite to dolomite, very little is known. It would seem, however, that under certain conditions magnesium sulphate or chloride from sea-water can replace a certain amount of calcium carbonate in a limestone, and form the double carbonate dolomite. This point will be raised in the conclusion, when discussing the results of Klement's experiments.

IV. Summary of Structural and Mineralogical Changes.

In this part of the work an attempt has been made to trace the sequence of the structural and mineralogical changes which the rocks have undergone. This sequence is described as far as possible in the order in which the changes probably occurred.

Under the microscope it is found that the rocks which have best preserved their original structures, and in which fewest secondary changes have supervened, are those from the fringing reefs of such islands as Niue, Vavau, and Christmas Island.

A section of a coral from one of these reefs shows the centers of calcification and spicular structure well developed, while the cavities of the coral are empty or partially filled with a fine calcareous "mud" derived from the disintegration of reef organisms.

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[1] Geological Magazine, 1888, pp. 66–73.

In a slightly altered coral it is noticed that the centers of calcification are less marked, and the "mud" in the cavities of the coral has been partially recrystallized.

A section of such a coral is seen in Figure 1, from the first terrace of Niue at a height of 80 feet.

Corals have been shown to be built up of aragonite fibers, and the spicular character of the skeleton seems to determine the mode of crystallization of the "mud." Lining the walls of the coral the "mud" is seen to have changed to long prismatic crystals of aragonite, deposited in crystallographic and optical continuity with the coral fibers. The aragonite crystals formed from "mud" are generally to be distinguished from the clear material deposited immediately from solution, by the presence of numerous opaque particles caught up in the crystals. Both types are met with in the limestones, but the aragonite deposited di-

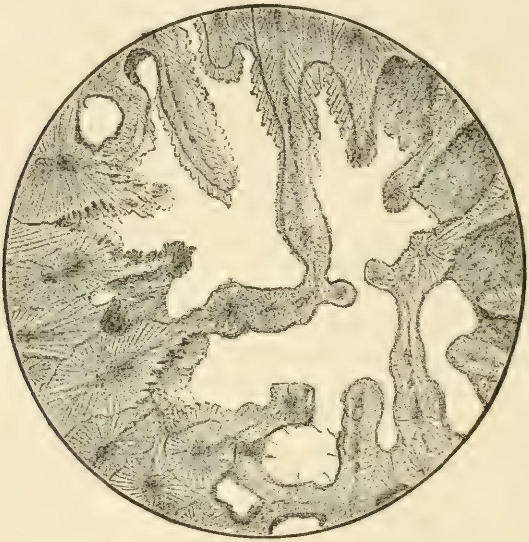

Fig. 1.

Niue, 80 feet. Section of a reef-forming coral showing spicular structure and centers of calcification. Cavities are partly filled with a dark mud which in places has altered to crystals of aragonite in crystallographic continuity with the fibers of the coral. × 30.

rectly from solution occurs much less frequently than that formed by the recrystallization of a calcareous "mud."

Another point of difference is that crystals deposited from solution grow from the walls of the cavity, and if they entirely fill it the crystals meet in the center in a serrated line, resembling the "comb structure" of a mineral vein. In a clarified "mud" no such definite arrangement of the crystals can be traced. A study of thin sections of rocks from coral islands seems to show that when crystallization occurs, either of a "mud" or from solution, calcite is in general the mineral which is first formed. Aragonite has been found almost exclusively as a lining to the cavities of corals whose spicular structure seems favorable to its formation. Figure 2 represents a section of a reef forming coral from the third terrace of Niue at a height of 200 feet.

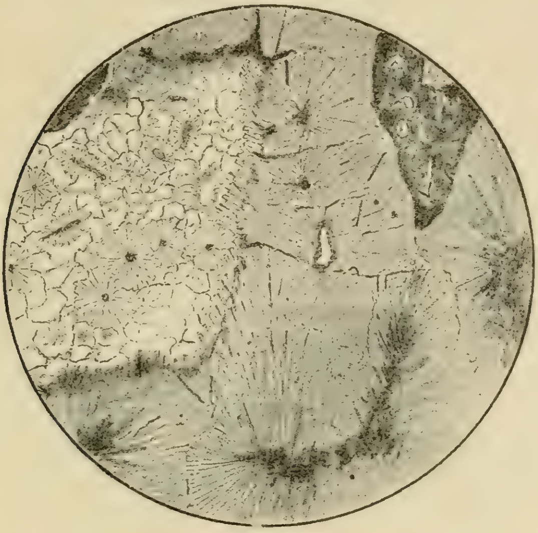

FIG. 2.

NIUE, 200 feet. Some cavities in the coral are filled with "mud," while others have recrystallized. Aragonite has formed on the coral wall and round the tubes of boring algæ, but calcite fills the remainder of the cavity. The spicular character of the coral is well seen. × 80.

Some of the "mud-filled" cavities remained unaltered, but others have been recrystallized. In the more central parts of these cavities the "mud" has crystallized as a granular mosaic of calcite, except round the tubes of boring algæ which are surrounded with radiating crystals, probably consisting of aragonite. It will be noticed that the "mud" lining the coral walls has crystallized in prismatic needles of aragonite deposited in optical continuity with the fibers of the coral.

The above description represents the appearances of the less altered reef-forming corals. The more commonly occurring constituents of the limestones are, however, compacted "coral sand," detrital fragments of organisms, and a certain amount of rubble rock. A section of a compacted "coral sand" is composed of organic fragments from the reef. As a rule, it shows aragonitic organisms such as coral fragments, Halimeda, gastropods, etc., together with organisms having calcite skeletons, such as most of the Foraminifera, echinid spines, Lithothamnion, etc.

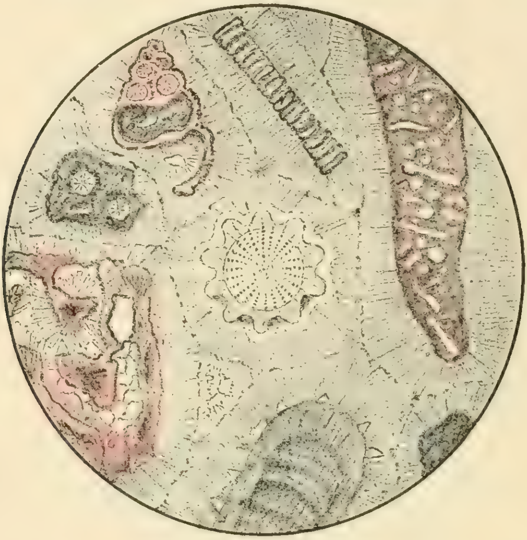

FIG. 3.

CHRISTMAS ISLAND, No. 372. (After boiling with cobalt nitrate.) The aragonite organisms, corals, gastropods, and Halimeda, as well as the aragonite crystals in the coral cavities, are stained pink. The calcite organisms, Orbitolites, echinid spines, and Lithothamnion, together with the fibrous calcite cement, are quite unstained. × 30.

The organisms are often fragmentary, and are cemented together by a matrix consisting either of "mud" or of calcite. The calcite may exist in two forms. The more usual is a somewhat clear granular mosaic of crystals, but frequently it coats the organisms with an investing layer of long fibrous crystals. A good example of the latter is seen in Figure

3, which consists of a section of a "coral sand" from the lower inland cliff of Christmas Island. The fibrous crystals of the matrix which radiate from adjacent organisms meet along straight lines and give a polygonal appearance to the rock section. This deposit of fibrous calcium carbonate was formed from solution probably on a beach between high and low tide marks. It could only be identified with certainty as calcite after the application of Meigen's staining method described above. After boiling with cobalt nitrate solution, it was noticed that the coral and deposited aragonite crystals, as well as Halimeda and the gastropod, with included aragonite, had been stained, while the echinid spine, Orbitolites, and Lithothamnion, together with the fibrous crystalline matrix, remained quite unaffected.

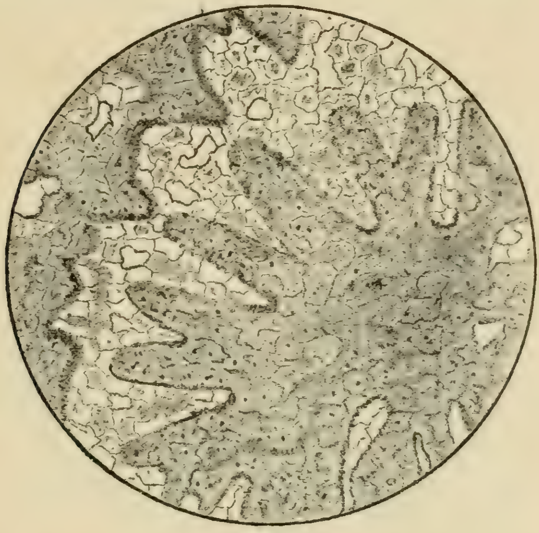

FIG. 4.

MAKATEA. Third terrace. The substance of the coral has been replaced by crystals of calcite. The coral walls are represented by "dirt lines," while the "mud-filled" cavities have been partially recrystallized. Many of the calcite crystals have dark centers. × 30.

In the newer rocks, of which the first three illustrations may be taken as examples, it will be noticed that the skeletons of all the organisms remain practically unaltered. When, however, older rocks are examined, it is seen that some of the organisms no longer have a fresh appearance. The tendency of the unstable form aragonite to pass over to the more stable form calcite has resulted either in the gradual conversion of the aragonite organisms into granular calcite without loss of the external boundaries, or, as frequently happens, this change is attended by the complete disintegration and obliteration of the organisms.

Figure 4 is in illustration of the first alternative.

It is a transverse section of a reef-forming coral from the third terrace of Makatea, and shows a coral whose cavity was originally filled with "mud." The stereoplasm has been replaced by a mosaic of almost clear calcite. The external wall of the coral can now be traced only by a thin dirt line, which possibly represents the impurities and organic matter extruded during the process of recrystallization. This must often be a very gradual process, because the tubes of boring algæ which are commonly found traversing the substance of the coral are occasionally preserved after recrystallization. It will be noticed that the "mud" within the coral cavity has shared in the recrystallization, and now consists of a mosaic of muddy crystals. The form of these crystals is

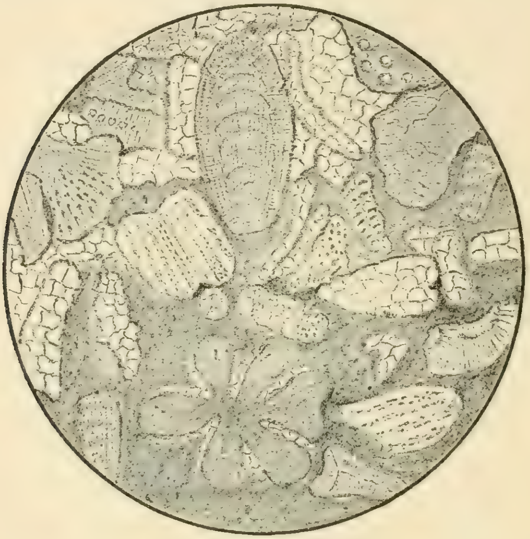

FIG. 5.

MANGO, 370 feet. A fragmental limestone partially recrystallized. Most of the matrix is "mud," but some has changed to calcite. Calcite organisms, such as Lithothamnion and echinid spines, remain unaltered; but aragonite organisms are represented by clear calcite and dirt lines round their external boundaries. × 30.

probably rhombohedral, but their mutual interference during growth has prevented them from showing their characteristic shape. Many of the calcite crystals have dark muddy centers, a feature which is quite commonly met with in dolomite, but occurs very rarely in calcite. The type of alteration just described is not peculiar to corals, but is shared by all the aragonite organisms occurring in the coral rocks. Figure 5 from Mango, at a height of 370 feet, is an example of a fragmental rock which has suffered such a change.

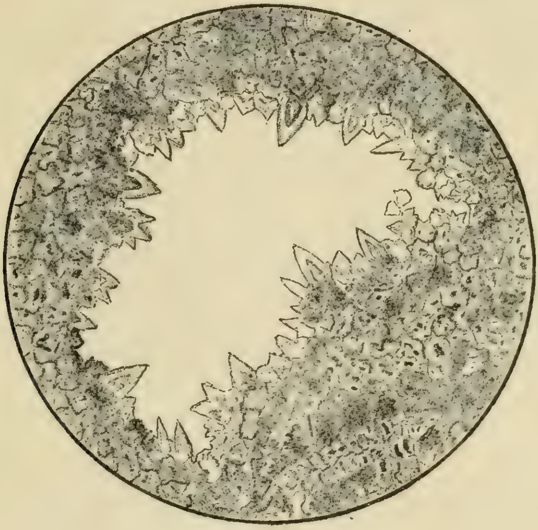

FIG. 6.

MAKATEA, 150–175 feet. The matrix of the rock consists of partially recrystallized "mud." The cavities are lined with large scalenohedral crystals of calcite, many of which are very clearly zoned. × 80.

The matrix was originally "mud," but has now in part been changed to definite crystals of calcite.

Most of the aragonite organisms such as corals, some molluscan shells, tunicate spicules, and Halimeda have also been recrystallized, the original borders of such as were present being represented by dirt lines. It will be seen that organisms such as Lithothamnion and echinid spines, whose skeletons consist of calcite, show no tendency to change, and for the most part are quite unaltered.

Although when calcite is formed, it is most commonly found to crystallize in rhombohedral crystals, yet occasionally a rock is met with in which the crystals are much more acute and consist probably of scalenohedra. This is more particularly true when the crystals are deposited from solution and line and project into cavities in the rock. This type of crystallization is seen in Figure 6, which represents a limestone from the central depression of Makatea.

The ground mass of the rock consists of "mud," some of which has been partially clarified in the process of recrystallization. The large cavity is seen to be lined with scalenohedral crystals of calcite, whose acute terminations project into the center of the cavity. One interesting and uncommon feature of these crystals is the marked zoning seen in many of them. This is probably due to the invasion of mud during crystallization, and while not uncommon in calcite from mineral veins is very rarely met with in crystals seen in sections of limestones. The above changes represent the normal structural and mineralogical alterations observed in these rocks, but there occur occasionally certain apparently anomalous features in the limestones. It has been noticed above that "mud" filling cavities in corals under certain conditions is converted into aragonite, but usually into calcite.

This is certainly true, but it is often noticed that the "mud" in a rock resists change after most of the organisms have recrystallized to calcite and even after another alteration, presently to be described, has still further obliterated the organic structure of the rocks. Where, however, the "mud" or other matrix in a rock becomes recrystallized it does not always happen that the organisms are also similarly altered at the same time. On the contrary, it has been occasionally noticed that the "mud" filling the cavities of a coral has become crystalline calcite, while the original aragonitic stereoplasm of the coral has broken down into a gray structureless "silt."

Many limestones, owing to the percolation of water containing carbon dioxide and to other causes, have passed or may pass through a series of changes such as has been described above. Whether or no a particular limestone, either unaltered or recrystallized, will undergo an important modification of composition and structure about to be described depends upon certain circumstances in the history of the rock about which very little is known.

This change consists in the introduction of magnesium into the limestone, and the partial replacement of calcium by magnesium carbonate. This replacement may go on in a rock until the amount of magnesium carbonate reaches as much as 15 per cent, and yet no sign of any mineralogical change may be noticed. Since dolomite and calcite are regarded as not being strictly isomorphous, if the magnesium carbonate occurred in the crystalline matrix of the rock it would be expected that crystals of dolomite should make their appearance. No such crystals are ever seen. It may be that an isomorphous mixture of calcium carbonate with magnesium carbonate may be possible up to about 15 per cent of magnesium carbonate, but if introduced beyond that amount, the stable compound dolomite is formed. A somewhat analogous change is described by Mr. L. J. Spencer, in connection with mixtures of copper and silver iodides.[1] On the other hand, it may be that the magnesium carbonate may be present in some form or another in the organisms. Unfortunately these are usually too small to be isolated for analysis. In this connection it may be mentioned that Högbom[2] quotes a series of analyses of specimens of Lithothamnion in which magnesium carbonate has been found forming from 3 to 13

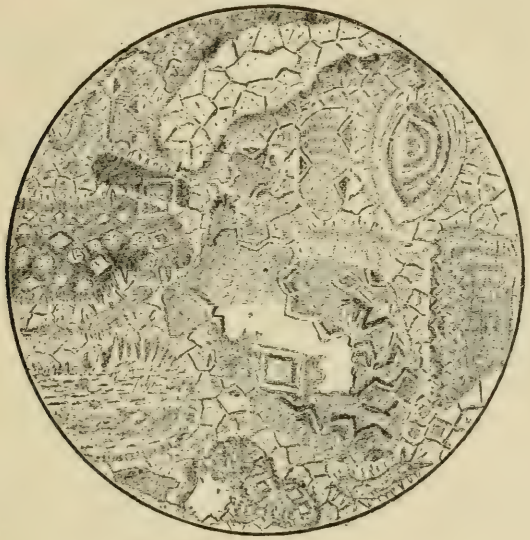

Fig. 7.

Christmas Island. No. 800. The matrix of the rock consists of dolomitic crystals, while a cavity is filled with clear dolomite. Some of the organisms have been incrusted with scalenohedra, while dolomite crystals have invaded some of them from without, inwards. × 30.

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[1] Min. Mag., June, 1901, pp. 43–44. [2] N. Jahresbuch für Min., 1894, I., 262.

per cent of the skeleton of the organism. When the amount of magnesium carbonate in a limestone rises above about 15 per cent, crystals of dolomite begin to make their appearance, at first in the matrix. As the amount of magnesium carbonate increases, the crystals become more plentiful, until a point is reached at which most of the matrix has been changed from calcite to dolomite. Even at this stage it often happens that no alteration has taken place in the structure of the organisms. The next change noticed is seen in Figure 7, a dolomitic limestone from Phosphate Hill, Christmas Island.

The matrix of the rock is almost entirely dolomitic, as are the clear crystals filling a cavity in the rock; while many of the organisms are incrusted with scalenohedral crystals. Crystallization has started to invade the organisms, and rhombs of dolomite are penetrating Lithothamnion from without inwards. It seems possible that the organism has already quietly absorbed magnesium carbonate without loss of structure, and that the present change is one of recrystallization. Certainly in some cases Lithothamnion which under the low power appeared to be almost unaltered, was found on examination with the high power of the microscope to have its cells filled with minute rhombohedra of dolomite. In the figure it is seen that dolomite crystals have filled and disintegrated the walls of the tubules of a Halimeda, that many of the dolomite crystals have regular zones of dirt, but that an echinid spine and an Amphistegina as yet show no sign of dolomitization. The order of disappearance of the organisms under dolomitization is not an invariable one, but it is usually noticed that Halimeda, if not already disintegrated, is one of the first organisms to disappear, while Foraminifera such as Orbitolites and Carpenteria and the alcyonarian spicules often resist dolomitization much longer. Lithothamnion is somewhat capricious. J. Walther[1] quotes a deposit in the Bay of Naples, in which Lithothamnion has disintegrated and formed a structureless limestone. He thinks the necessary condition for this to occur is that the organism should be subjected to percolating water. The decomposition of the animal matter within the organism gives rise to carbon dioxide, which, dissolved in the water, attacks the skeleton of the organism and dissolves it partly away. There is no doubt that in these coral limestones sometimes Lithothamnion does lose its structure comparatively easily, but, as a rule, the conditions have been favorable to its preservation, and it is found to be one of the most persistent forms. Other forms which seem to be at least equally persistent are such

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[1] Zeitsch. deutsch. Geol. Ges., 1885, Vol. XXXVII., p. 329.

Foraminifera as Amphistegina and Heterostegina and the echinid spines.

The last stage in the dolomitization of a limestone, originally crowded with organic fragments, consists in the extension of the invasion of the organisms by dolomite crystals and the ultimate destruction of all traces of their organic character. This results in the formation of a structureless dolomite consisting entirely of clear or muddily zoned crystals. It is often noticed that partly as a result of solution, partly of consolidation under recrystallization, the rock assumes a more or less cavernous appearance.

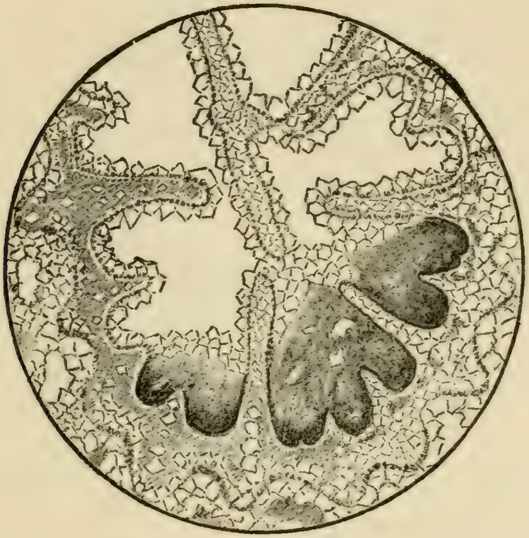

FIG. 8.

NGILLANGILLAH, 25 feet. Section of a dolomitized coral. The stereoplasm of the coral is now replaced by a dolomitic "silt," while the external and internal walls are represented by "dirt lines." Opaque "mud" in the cavities remains as calcite, and subsequent to its deposition, dolomite crystals, formed from solution, have incrusted the walls of the coral. × 30.

A somewhat parallel series of changes under dolomitization can be traced in the case of a coral section. Some of these changes can be seen on reference to Figure 8, which represents a section of reef-forming coral from the dolomitized island of Ngillangillah.

At a comparatively early stage in the history of the coral, some of its cavities were filled quite up to the wall of the coral with a dark "mud" containing small fragments of organisms. Subsequently, dolomite crystals were deposited on the coral walls which can now be traced by a dirt line. The substance of the coral has been broken down, and its place is now taken by a fine gray dolomitic "silt," in which larger crystals of dolomite have formed. On applying Lemberg's test to a thin section of this rock, it is found that, in spite of dolomitization, most of the "mud" in the slide becomes stained, showing that it still consists of a finely divided calcite.

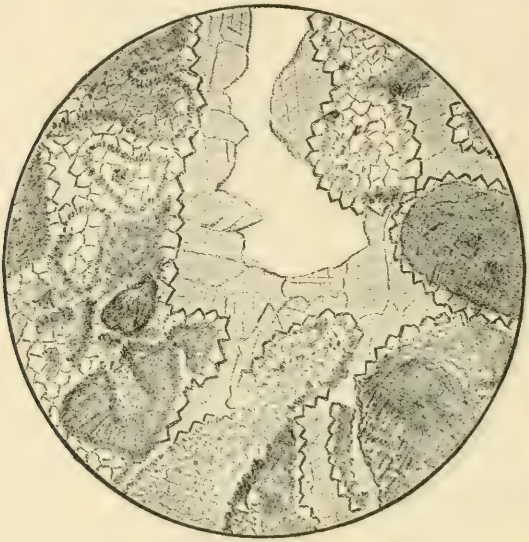

Fig. 9.

Mango, 290 feet. A much altered cavernous dolomite, whose cavities are now nearly filled with large crystals of secondary calcite. × 30.

After the complete dolomitization of a rock, it is noticed that cavities are often filled or partly filled by the further deposition of crystals apparently from solution. This deposited material consists sometimes of dolomite, in which case the composition of the rock is not much changed; in most cases, however, the material deposited consists of broad crystals of calcite.

Figure 9 illustrates this point, and represents a section of a fragmental limestone from Mango at a height of 290 feet. The figure shows that the limestone has been thoroughly dolomitized, and as a consequence the organisms are largely obliterated, while cracks and cavities have arisen in the rock. These have been subsequently filled with secondary calcite, forming broad slightly yellow crystals showing the characteristic cleavage, and ramifying into the cracks and cavities in the limestone. In this way the bulk analysis of a dolomitic limestone may be profoundly modified so that a dolomitic rock in which all organisms have been destroyed may, as a result of the infiltration of calcite, have its percentage of magnesium carbonate lowered from over forty to twenty or even under.

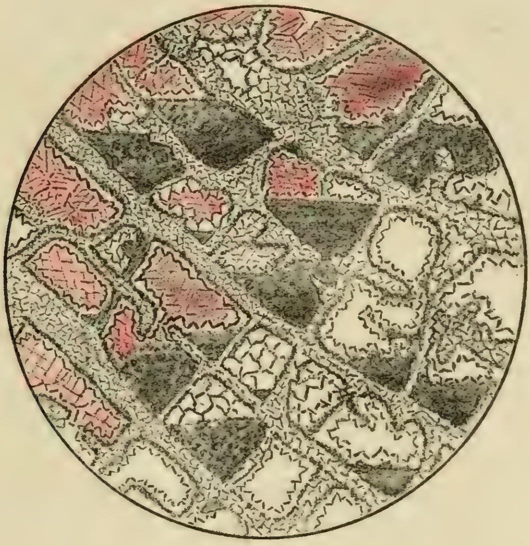

FIG. 10.

MANGO, 320 feet. (After staining with Lemberg's reagent.) A longitudinal section of a dolomitized coral. "Mud-floors" are seen partly filling cavities. Subsequently an incrusting layer of dolomite crystals was deposited, and finally many remaining cavities have been filled with secondary calcite which is now stained red. × 30.

Figure 10, from Mango, at a height of 320 feet, shows how this change affects the appearance of a dolomitized coral. Some time before dolomitization started many of the cavities in the coral were filled up to a particular level by calcite mud slowly settling down from muddy water. The horizontality and general parallelism of these "mud floors" constitutes a marked feature in some longitudinal sections of reef-forming corals. It will be noticed that the "mud" extends quite up to the coral wall, showing that it reached its present position before the deposition of dolomite crystals began. Dolomitization subsequently invaded the substance of the coral, and crystals were deposited on the walls and on the surface of the "mud floors." Finally, many of the remaining spaces in the coral were filled with clear, slightly yellow crystals of calcite. On treating the section with Lemberg's solution, the secondary calcite is stained pink, while the mud in the cavities does not stain. Apparently during dolomitization, the calcite mud was quietly replaced by dolomite without any sign of recrystallization having taken place in the rock.

Two points of interest which arise in some dolomitic limestones remain to be recorded. It is well established that many dolomitized limestones consist entirely of rhombohedra of dolomite with dark, muddy-looking centers. As analyses of such rocks rarely show more than 40% of magnesium carbonate, it has been surmised that the muddy material in the centers of the crystals consisted of calcite. The author has demonstrated this to be the case in some sections of these rocks by treatment with Lemberg's solution when the muddy centers of the crystals become clearly stained by the reagent.

Finally it has been shown by the use of Lemberg's reagent on some of the rocks from Mango, that many quite colorless rhombohedra which appeared to be dolomite really consisted of alternate zones of calcite and dolomite apparently in optical continuity with each other. The author is not aware that this feature has been described before, and it appears to throw some light on a possible mode of formation of dolomite. This zoning may be explained in two ways.

It is possible that each crystal consisted originally entirely of calcite, and that alternate zones formed during the growth of the crystal possessed slightly different physical structures. When the rock was subjected to the conditions producing dolomitization, certain zones were converted into dolomite, while the rest of the crystal remained as calcite.

The alternative to this view is that the crystals originated in much the same way as artificially zoned crystals of alum are made. The crystal may have been originally dolomite or calcite, but from time to time the character of the solution in which the crystal formed changed in such a way as to determine the deposition alternately of dolomite and calcite *directly from solution.* The author believes this view to be more probable, and it seems to receive support both from the examination of the dolomite crystals found lining cavities in sections of some of the dolomitized limestones, and also from a macroscopic study of hand specimens which occasionally contain large cavities lined by concentric layers of incrusting dolomite crystals.

V. Conclusion.

In reviewing the facts which a chemical and microscopical examination of these coral limestones has elicited, it will only be possible at this stage of the inquiry to notice briefly three of the more prominent questions which arise. These are: — (A) The constitution and probable origin of the coral limestones, (B) their geological age, (C) the relation of the distribution of magnesium carbonate in the limestones to the question of the origin of dolomite.

A. The published accounts of the several islands, together with the detailed microscopical examination of the rocks, show that the limestones, apart from the bedded basal limestones dipping at 15°, are mainly of two types. True coral reefs occur here and there among the older rocks of the different islands, but are usually confined to the modern fringing reefs, which are now found on the slopes of the elevated islands, and were probably formed during pauses in the movement of upheaval.

The greater part of the masses of these upraised coral islands consists, however, of fragmental rocks, made up of pieces of reef-forming corals, together with the other organisms usually associated with corals in a reef. Globigerina and other deep-sea forms are found occasionally, but only in numbers approximating to those met with drifted into the lagoons of existing reefs. The evidence of the organisms as a whole, together with the intercalation of true reefs, shows that these fragmental deposits were laid down under shallow water conditions close to a true reef. The great thickness of these rocks may be accounted for in some cases by the outgrowth of a reef on its own talus during a period in which no vertical movement took place. Mr. E. C. Andrews is of the opinion that the bedded limestones dipping at 15° and interbedded with "soapstones," which form the basal rocks in the Fijis, were formed by subsidence, but that the unbedded limestones and reefs of later age were formed during intermittent periods of elevation, and form only a veneer of coral limestone, more or less perfectly masking the older bedded foraminiferal rocks.

B. The age of the older central limestones which form the greater part of the elevated coral islands has been determined with a fair degree of certainty in a few cases.

Prof. Rupert Jones and Mr. Frederick Chapman,[1] when examining the Foraminifera from Christmas Island, discovered in the oldest limestone a form of Orbitoides, only known elsewhere from Oligocene and Eocene rocks, while higher up in the series other forms of the same genus occurred, which were correlated with certain forms found in Java, Sumatra, India, and other localities from rocks of Miocene age. The highest rocks of the plateau were doubtfully referred by Dr. C. W. Andrews to the Miocene on the report of Dr. Gregory on the fossil corals. Since the publication of the monograph on the Island, more sections have been cut, and I met with Orbitoides from two rocks collected near Phosphate Hill, so that the Miocene age of the rocks of the plateau is now fairly well established. The age of the inland cliffs and fringing reefs cannot be fixed with certainty. The Foraminifera, with the exception of rolled fragments of Orbitoides, all belong to forms still existing, but Dr. Andrews thinks that the upper inland cliff may be of lower Pliocene age, the lower inland cliff later Pliocene, while he assigns a Pleistocene age to the shore cliff. With regard to the rocks of the raised limestones of the Fijis, Tongas, etc., Mr. Agassiz maintains[1] that they consist mainly of Tertiary masses of limestone, an opinion largely based on their altered appearance and their relation to the undoubtedly more modern fringing reefs and terraces which occur on some of their slopes. I am able to confirm this opinion by fossil evidence from two of the islands of the Fiji group. In Mango a form of Orbitoides occurs at a level of 310 feet, which Mr. Frederick Chapman kindly identified for me as *Orbitoides sumatrensis,* a Miocene form from Christmas Island, Sumatra, and Borneo. The rock in which it occurs is, therefore, presumably of Miocene age.

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[1] Monograph of Christmas Island, 1900, pp. 226–264.

One of the limestones from Namuka, another of the Fiji group, also contains a form of undoubted Orbitoides, which was, however, not capable of being specifically identified. It seems not unreasonable to suppose, that if more sections of these limestones were examined, the distribution of the genus Orbitoides over the islands in the Pacific would be still further enlarged.

C. The literature in relation to the question of dolomite is so large that it would be quite impossible within the limits of this present paper to discuss the subject adequately, but it may not be out of place to summarize a few of the more important opinions, which from time to time have been put forward by chemists and geologists in explanation of its formation. Gustav Bischof[2] gave an admirable account of the results of the earlier workers on the question of dolomite, and made many experiments himself. He showed: —

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[1] Bull. Mus. Comp. Zoöl., 1899, Vol. XXXIII., p. 10.

[2] Chem. and Phys. Geology, 1859.

(1) By dissolving mixtures of calcium and magnesium carbonates in water containing carbon dioxide, and then evaporating the solution at 122° F., that under these conditions the calcium carbonate was completely precipitated, while most of the magnesium carbonate remained in solution.

Hence dolomite could not be formed under ordinary conditions by the evaporation of water containing the two carbonates in solution.

(2) That the amount of carbon dioxide present in meteoric water sufficed for the production of a saturated solution of calcium carbonate.

(3) That in limestones containing magnesium, water saturated with carbon dioxide dissolved out only the calcium carbonate. Even when 11.5 % of magnesium carbonate was present only a trace of it was removed.

He quoted also examples of limestones containing up to 68 % of magnesium carbonate. In these cases the carbonates were not chemically combined, since dilute acetic acid dissolved out calcium carbonate alone. With true dolomite, the carbonates, when attacked, were dissolved out in molecular proportions.

The association of the dolomites of the Tyrol, with volcanic rocks rich in magnesia, led Von Buch[1] to suggest that the formation of dolomite was due to the eruption of volcanic rocks into a limestone, and that the change was brought about by the vapor of magnesium chloride.

Haidinger[2] attributed its formation to the action of magnesium sulphate on a limestone, under great heat and pressure.

Von Morlot[3] held a similar view to Haidinger, and by heating magnesium sulphate and calcium carbonate in a sealed tube to a temperature of 392° F., succeeded in forming a double carbonate.

Marignac[4] obtained a like result by substituting magnesium chloride for magnesium sulphate.

All these writers assumed that the formation of dolomite is connected with the intrusion of igneous rocks.

Later, Forchammer[5] suggested the reaction of spring-water, containing much calcium carbonate, with sea-water at a high temperature, as a possible cause of the precipitation of the double carbonate of calcium and magnesium.

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[1] Ann. de Chim. et Phys., XXIII., p. 296.

[2] Poggend Annal., LXXIV., p. 591.

[3] N. Jahrb. für Min., 1847, p. 862.

[4] N. Jahrb. für Min., 1849, p. 742.

[5] Ann. de Chim. et de Phys. XXIII.

Prof. J. D. Dana,[1] after the discovery of magnesian limestone from the island of "Metia" (Makatea), advanced a theory of dolomitization, as applied to coral islands, which has been very largely accepted. He stated that the sea-water was the source of the magnesium, and that this is introduced during the consolidation of the limestone below the surface.

T. Sterry Hunt[2] stated two ways in which dolomite might be formed. The first consisted in the action of bicarbonate of lime upon solutions of magnesium sulphate, in which case gypsum was a subsidiary product. The second method was the reaction between river-water, containing sodiumb icarbonate, and sea-water in shallow basins, and the consequent decomposition of calcium chloride and magnesium sulphate into calcium magnesium carbonate, which, by subsequent heating, was converted into dolomite.

E. T. Hardman,[3] in his paper on the dolomites of the Carboniferous limestone of Ireland, contended that the alteration of Irish limestones to dolomite was due to the greater solubility of calcium carbonate in limestones containing some magnesium carbonate when acted on by water containing carbon dioxide in solution at atmospheric pressure. In support of this he quoted experiments he had performed on limestones containing some magnesium carbonate. He found, like Bischof, that under atmospheric pressure the calcium carbonate was dissolved and the magnesium carbonate was unaffected. Under high pressures magnesium carbonate alone was dissolved[4] from the mixed carbonates, and this method was formerly used commercially in the preparation of magnesium carbonate from dolomite.

In 1895 Klement[5] published a paper on the artificial formation of dolomite. He heated the finely powdered mineral or organism together with crystallized magnesium sulphate and a saturated solution of sodium chloride in a closed retort to a temperature of about 100° C. for two or three days. He then determined the percentage of magnesium carbonate in the washed precipitate. Under these conditions calcite took up only a trace, aragonite absorbed 34.6 per cent, while various corals yielded from 38.5 to 41.9 per cent of magnesium carbonate.

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[1] Geology of United States Exploring Expedition, 1849, p. 153.

[2] Chemical and Geological Essays, p. 90.

[3] Proceedings Royal Irish Academy, 1877, pp. 705–730.

[4] Dingl. Polyt. Journ. CC. IX., p. 467; also Abs. Journ. Chem. Soc., Vol. XII., p. 96.

[5] Ueber die Bildung des Dolomit, Tscherm, Min. Pet. Mitt., 1895, XIV., p. 526.

In 1898 Mr. Stanley Gardiner[1] attributed the dolomitization of coral islands to the greater insolubility, in water containing carbon dioxide, of the double carbonate of calcium and magnesium over that of either calcium or magnesium alone. He believes this causes a concentration of the magnesium carbonate in certain limestones, and that this concentration may be aided at times by the evaporation of the spray from sea-water.

It is clear, in view of the distribution of dolomite in coral islands that the early views of Von Buch, Haidinger, Von Morlot, and Marignac are quite untenable if applied to the dolomitization of such structures. A study of the results of analyses from different localities shows that there is no necessary relation between dolomitization and the presence of volcanic rocks. Although Christmas Island, Mango, and other islands which are partly volcanic also contain dolomitic rocks, yet, in most cases, the volcanic rocks are immediately associated, not with dolomite but with a non-magnesian limestone. Again, no dolomitization has been discovered in the volcanic island of Guam. On the other hand, islands such as Vatu Vara and Ngillangillah, in which no volcanic rocks have been found, are dolomitized from top to bottom. The views of T. Sterry Hunt are open to several objections. The formation of gypsum, associated with dolomite, appears to militate against his first view, since gypsum has only been recorded from two or three coral islands, and never, so far as I am aware, in association with dolomite. The gypsum from raised atolls is, however, derived from sea-water by simple concentration, while that from the double decomposition of magnesium sulphate and calcium carbonate might be kept in solution in sea-water by means of its greater solubility (1 in 400) than that of dolomite. His second explanation involves the mixing of river-waters, containing sodium bicarbonate in solution, with sea-water, a condition which is not realized in the neighborhood of coral islands.

Hardman's views were advanced to explain the local dolomitization of the Carboniferous limestone of Ireland and could not apply to islands such as Vatu Vara and Ngillangillah where apparently the whole islands are dolomitized. At the end of his paper he remarks that it is probable that deposits like the magnesian limestone may be due to evaporation and assimilation of magnesium carbonate by animals in the lagoon and subsequent alteration to dolomite; and that only in this way could large masses of dolomite be formed. Stanley Gardiner's views appear to be very similar to Hardman's, and can only have a very local application. Most limestones contain not more than two or three per cent of magnesium carbonate, and consequently to form a dolomite from a rock of this character would require a very extensive solution and concentration of the original limestone. The experiments of Klement, in 1895, demonstrated that the unstable mineral aragonite is much more susceptible of the invasion of magnesium carbonate than the stable form calcite. The conditions under which the experiments were performed make a strict comparison with reef dolomitization difficult. The results are, however, very suggestive as showing that magnesium sulphate can, under certain conditions, react with calcium carbonate. The stable compound calcium magnesium carbonate is deposited, while the by-product calcium sulphate can be kept in solution by dilution. It may be that the reaction which proceeds quickly under conditions of great concentration and high temperature may proceed slowly, but no less surely, in superficial waters such as those of a lagoon which is maintained for a sufficiently long period of time under uniform conditions.

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[1] Proc. Camb. Phil. Soc., 1898, Vol. IX., Part VIII., pp. 417-503.

Recently it has been suggested that the introduction of magnesium into a coral limestone is only effected when the rock has been submerged for some time to a considerable depth corresponding to a particular pressure. This view is, however, not in harmony with the facts at Christmas Island, Mango, Vatu Vara, Ngillangillah, etc., where the highest rocks of the island are dolomitized, and the only movement of which there is evidence since their formation in shallow water is one of elevation. It is true that denudation has removed a certain thickness of rock since their elevation, but there is evidence that in the islands mentioned the effects of denudation have not been extensive.

It will be seen that most of the opinions which have been put forward to explain the introduction of magnesium carbonate into coral rocks do not agree with the facts herein recorded as to the distribution of dolomite in upraised coral islands. There yet remains Dana's well-known theory of dolomitization, and perhaps some modification of it will be found to harmonize more closely with the evidence than any view which has, as yet, been put before geologists. The occurrence of dolomite at the summits of many of the islands is significant. At Christmas Island dolomite is found near the summits of the highest hills immediately below beds of phosphate. Dr. C. W. Andrews believes that after Miocene times the movement of subsidence to which the formation of the older limestone is due, ceased, and a very long period of rest ensued, during which the only land masses rising above the lagoon were the low islets now forming Murray, Ross, and Phosphate Hills. The accumulation of guano from the droppings of sea birds, and its subsequent alteration of the limestone by percolating water, formed the beds of phosphate now found capping these hills. The occurrence of beds of dolomite immediately below the phosphate seems to point to its *formation in waters near the surface*, possibly those of the lagoon. The occurrence of dolomitic rocks from the inland cliffs and terraces of Christmas Island and Eua seems to support this view, although these dolomitic limestones may be derived from the débris of the older rocks of the central nucleus of these islands. Mr. E. C. Andrews states, however, that the lower dolomitic limestones of Ngillangillah are from a fringing reef. This view is supported by the fact that the upper raised fringing reefs in the Red Sea are dolomitized.[1] It seems probable that the introduction of magnesium into the limestones does take place from the waters of the lagoon under certain favorable conditions. What these conditions are it is at present impossible to say with any degree of certainty. It is improbable that concentration to any marked extent can take place in lagoons unless they are entirely shut off from the sea. Before this question can be attacked successfully much fuller information must be obtained as to the chemical composition of lagoon muds, and analyses must be made of the waters of lagoons and those of the open ocean outside coral islands. It may be that the carbon dioxide liberated on the death and decay of both plants and animals helps to dissolve their calcium carbonate, which under these conditions may react with magnesium sulphate of the sea-water, and precipitate the insoluble double carbonate of calcium and magnesium, while the more soluble calcium sulphate, formed as a result of the reaction, could remain in solution. Whatever the conditions for the introduction of magnesium carbonate into coral limestone may be, it seems probable, from the distribution of magnesium carbonate in upraised coral islands, that the introduction takes place at or near the surface of the water, and that a limestone exposed to suitable conditions for a sufficiently long time will become dolomitic. The occurrence of dolomitic limestones at several horizons in an island might be accounted for either on the theory of subsidence or of elevation, by changes in the rate of movement of depression or upheaval. An ordinary non-magnesian limestone might result from a somewhat rapid subsidence or elevation, while a constant and slow subsidence or upheaval might result in the formation of a completely dolomitized island. The extent to which a rock will become dolomitic must depend largely on the duration of the exposure of the limestones to the conditions producing dolomitization.

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[1] Walther, J. Abhandl. math. phys. Königl. Sachs. Gesellschaft der Wissenschaften Bd. xiv. p. 494, Hume, Rift Valleys of E. Sinai. Int. Geol. Cong. Paris, 1900, pp. 32–40.

In conclusion it must be stated that this paper is necessarily incomplete, and is only intended as a first contribution towards the chemical and microscopical examination of upraised coral islands. It is hoped, however, that the results which have been obtained may not be without interest to geologists, and that some of the facts may help to throw light on the fascinating problems which have for so long been associated with coral reefs.

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THE MOUNTAIN RANGES OF THE GREAT BASIN.

By W. M. Davis.

With Seven Plates.

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Historical Statement. — The larger mountain ranges of the Great Basin offer problems of especial interest, inasmuch as the faulting by which their present relief is believed to have been produced is not proved by stratigraphic evidence of the kind familiar to geologists, but by physiographic evidence of a kind to which little attention is usually given. These ranges were described by King in 1870 as "ordinarily the tops of folds whose deep synclinal valleys are filled with Tertiary and Quaternary detritus" (a, 451). Soon afterwards Gilbert concluded that the individual ranges were the carved upper parts of tilted or lifted blocks, resulting from "the displacement of comparatively rigid bodies of strata by vertical or nearly vertical faults" (1874, a, 50). The same view was elaborated in a later report (1875, b, 21–42). Powell, Dutton, and Russell adopted essentially the same explanation. King also seems to have recognized the validity of Gilbert's conclusion, for in 1878 he modified his earlier views by recognizing frequent faulting at a later date than that of the folding by which the great anticlinals and synclinals had been produced (b, 735). None of these observers, however, gave explicit consideration to the three elements necessarily involved in the problem of block faulting; namely, the prefaulting topography, the topographic effect of the faulting, and the work of erosion on the faulted blocks.

The latest general discussion of the region is by Spurr, in whose essay a review of earlier writings may be found. This author concludes that "the mountain fronts studied are, in general, not marked by great faults, and, conversely, that the ascertainable faults are very rarely attended by simple fault scarps." He therefore rejects Gilbert's hypothesis and explains the Basin ranges as the "results of compound erosion active since Jurassic times, operating on rocks upheaved by compound earth movements which have been probably also continuous during the same period." It is further suggested that the ranges were probably differentiated during Cretaceous time, when a greater precipitation is assumed to account for their dissection: "subsequently the climate became arid and the water supply was not sufficient to remove the detritus from the valleys, which filled up" (1901, 265, 266). I have elsewhere briefly stated the reasons why this explanation seems unsatisfactory (1901, a).

The Basin ranges have for some years been of special interest in systematic physiography, for if Gilbert's explanation of them is correct, they offer unusually simple examples of mountain uplift and sculpture; examples that may be adduced as relatively elementary illustrations of the difficult group of mountains in general, and that may therefore be with propriety presented to beginners for introductory practice before the description of complicated mountain ranges is undertaken. This opinion was confirmed on the appearance in 1884 of Russell's vivid account of the faulted lava-block ranges of southern Oregon; for these seemed to be even simpler and younger than the ranges farther south. Ranges of this kind are of a further interest in that they support in a certain measure the more primitive theory of mountain-making; namely, that mountains are the immediate results of uplift, comparatively little modified by erosion, while the intermediate troughs are the effects of depression: in a word, that dislocations of the earth's crust are here chiefly responsible for the observed relief of the region, and that the part played by erosion is subordinate. It is now generally agreed that this primitive theory finds little support in such ranges as the Alps, where the existing forms of peak and pass, spur and valley, are the product of extensive erosion in a deformed and broadly uplifted mass. A recurrence to the older theory in explanation of the ranges of the Great Basin is therefore a wholesome discipline.

It has for some time seemed to me that there was good evidence for regarding the Oregon lava-block ranges as types of the youngest, most elementary mountain forms known to geographers, and for placing the ranges of the Great Basin in Utah and Nevada as types of larger and more maturely sculptured ranges, appropriately following the introductory examples of southern Oregon. In view of this relation of the Basin ranges to the problems of systematic physiography, the opportunity of seeing some of them last summer was especially welcome, even though the time that could be given to them was brief. The conclusion reached was that faulting has recently exercised and indeed still exercises a dominant control over the uplift of all the larger mountain ranges observed, but that erosion has greatly modified the form which would be produced by faulting alone, and that the prefaulting form is for this reason generally not recognizable.

Theoretical Considerations. — It seems desirable to present the observations that have led to this conclusion in an order that is suggested by a deductive consideration of the problem, such as is necessarily entertained in the establishment of ideal physiographic types of mountain forms. In this way the complete ideal types of carved block mountains may be first carefully conceived and visualized in the imagination, all their essential features being systematically developed. The observed elements of form may then be described in their proper relation to the whole of which they are believed to be but parts.

The various types thus conceived in the imagination must represent all the hypotheses by which the facts in hand may be explained, the advantages that follow from a due consideration of "multiple-working hypotheses" having been convincingly set forth by Chamberlin. In publication, however, it is permissible to give relatively little space to those hypotheses which have been proved incompetent during the progress of an investigation, and to set forth in detail only the one which has gained — in the author's opinion at least — the rank of a successful theory. For this reason, the following pages are chiefly devoted to a consideration of the Basin ranges as dissected fault-block mountains.

The author feels that some apology is needed for his writing on a field where his own observations are very limited in comparison to those of others who have a much wider experience in the Cordilleran region. His reason for adding yet another essay to the already abundant literature on the mountain ranges of the Great Basin is chiefly that the articles thus far published have not included a detailed analysis of the problem in hand, and in particular that the effects of erosion upon the faulted mountain blocks have received but little consideration. Gilbert's brief statement, written thirty years ago as the result of his first western expeditions in 1871, 1872, and 1873 (b, 40, 41), is hardly more than a summary of conclusions. Russell explains the Basin ranges as having been "formed by the orographic tilting of blocks that are separated by profound faults" (a, 8), and leaves the erosion that they have suffered to be inferred. Elsewhere, when describing the West Humboldt range, he says: "The precipitous mountain face . . . is in reality an ancient fault scarp of grand proportions, which was somewhat eroded before the existence of Lake Lahontan" (a, 277); but "somewhat eroded" does scanty justice to the fine sculpturing of this range as shown in the accompanying Plate XLV. Spurr distinguishes between scarps directly due to faulting, and scarps due to the erosion of a long-ago faulted mass; but he gives no explicit discussion of the forms assumed by a simple fault scarp as it undergoes dissection; and his attention to the physiographic features of the Basin ranges in general is so brief that he implies that they possess an intimate correlation of structure and form by saying that the Appalachians "likewise consist of parallel ridges eroded along lines of folding" (255).

In spite therefore of the many descriptions of the Basin ranges that have been published, there has not yet appeared any detailed statement of the theory by which they are explained; the essential consequences of the theory have not been explicitly formulated; the criteria by which a fault-block mountain may be recognized in early or later stages of dissection have not been defined; and it is to supply these deficiencies that the preparation of this essay was undertaken.

When the essay had reached an almost completed form, the writer had the advantage of hearing the Basin range problem discussed by Mr. Gilbert at the Washington meeting of the Geological Society of America, in January, 1903. It was a gratification to find that the plan of presentation here adopted very closely resembled in various ways the treatment offered by the originator of the Basin range theory: it was at the same time an embarrassment to see that many of these pages would be hardly more than repetitions of Mr. Gilbert's report. They may, however, have a certain value in so far as they show that independent study leads to accordant results.

Ideal Types of Fault-block Mountains. — There are two chief types of fault-block mountains as illustrated in Figures 1 and 2: one shows what may be called a tilted block, the other a lifted block. In order to economize space, only the tilted block type will be here considered in detail.

The most characteristic features of a typical tilted block mountain in its youth or early maturity may be summarized in Figure 1 in which the block, ACE, has been raised and more or less inclined. The upper part, BC, of the faulted face, AC, rises above a piedmont plain of waste, BD, by which the backward slope of an adjoining block is buried; while the backward slope of the block, CE, is also partly buried in a plain of waste, FJ, which meets another waste plain from a third faulted block, EK.

Certain features shown in the figure are essential to the type in the stage of erosion here considered. The fault-bounded block, ACE, must present a back-sloping surface, CFE, whose form before the faulting occurred is now more or less modified by erosion in its exposed part, CF, and buried under waste in its depressed part, AB. The lower part, AB, of the faulted face, ABC, is buried under the waste derived from the exposed and more or less dissected part, BC. Blocks which stand so high that the trough between them is now dissected instead of aggraded are not here considered. Examples of this kind are described in the northern Sierra Nevada by Diller (1886, 12–16).

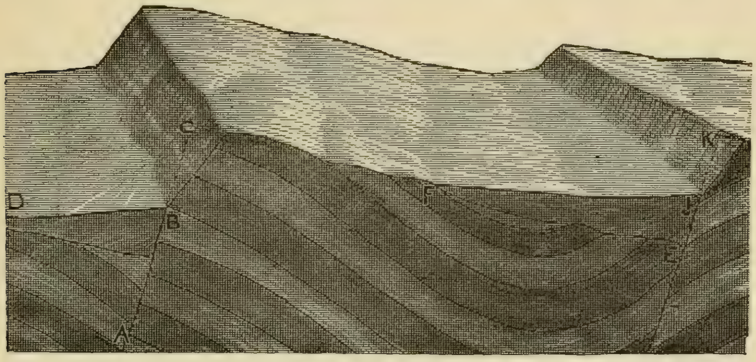

FIGURE 1.

Diagram of a tilted block; youthful stage.

Other features of the type are extremely variable. The size, structure, and form of the block are entirely undefined. Its upper surface may have been in the prefaulting period, a peneplain worn down on ancient schists; a mountain area of folded or faulted strata more or less subdued by erosion; a series of horizontal and slightly dissected aqueous or igneous strata; or anything else. The block faulting may be on a large or small pattern; of regular or irregular arrangement; reaching over an extensive or a restricted area; of great or little displacement; and with much or little tilting.

The displacement may be slow or rapid, uniform or variable in rate, of brief duration or long continued, of remote or recent beginning and ending; it may vary greatly in amount along the fault line, diminishing to its end; as faulting continues, the length of the block may increase, and its end will thus vary in position. The faults may be simple or complex; the faulted front of a block may be clean cut, stepped, or shattered; the fault line along the mountain base may be essentially indifferent to the structure of the block, for the fault may be of deep-seated origin and not necessarily guided by the pre-existent foliation, stratification, folding, or faulting that is seen in the upper part of the block. The fault surface may be nearly a plane or a conspicuously curved surface, but from all that is known of faults it cannot possess sharp or exaggerated irregularities such as are seen in the septa of an ammonite. The uplift and tilting may vary widely in the different examples of a single district. Appropriate to all these variable elements, the present form of a faulted block may exhibit little or much modification by erosion; little modification being consistent with rapid and recent faulting of a resistant block in very arid climate; much modification being consistent with slow and ancient faulting of a weak block in a climate of sufficient rainfall to produce active erosion. In a block whose length has been increasing during a long time of increasing displacement, it would be reasonable to expect a mature dissection near the middle of the block to give way to young dissection near the ends of the block; for the middle part will have been long exposed to erosion while the ends will have been but lately uplifted. The prefaulting form of the block surface will usually be longest preserved near the base of its exposed back slope, CD, and the form due immediately to faulting will be best seen near the base of the front, CB.

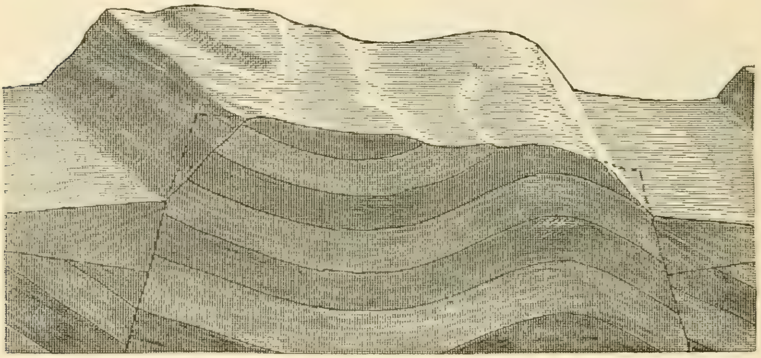

FIGURE 2.

Diagram of a lifted block; youthful stage.

As long as the faulting and tilting continue, strong relief may be maintained; but after displacement ceases, erosion will advance without more hindrance than is offered by the resistance of the rocks; it will slowly subdue the earlier relief to rounded forms, and still more slowly widen the valleys and consume the intervening hills as the forms of old age, Figure 3, are realized. In a late stage of degradation, the mountain mass will be invaded by numerous flat-floored, branching valleys between low, rounded forking spurs. The valleys will then be largely adjusted to the weaker rock structures, while the fading ridges will stand longest where upheld by the resistant structures. The mountain base, an irregular line, will have no close relation to the path of the fault, and the slope between the mountain base and the fault line will carry a thin and discontinuous veneer of waste on a planed rock floor. It would probably be impossible to distinguish the residuals of tilted and lifted blocks in a late stage of erosion.

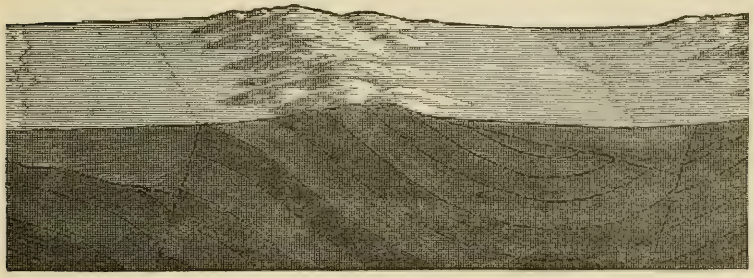

FIGURE 3.

Diagram of a tilted block; old stage.

Place and Value of Deduction. — It is important here to emphasize two general considerations. First, the details of form appropriate to any desired special case under the ideal type should be deduced with as much completeness and definiteness as possible. As long as the details of a theoretical form are vaguely conceived, the observer will be unable to give his theory a rigorous test; its consequences will be so indefinite that he can hardly say whether they are confirmed or contradicted when he confronts them with the appropriate facts of observation. It is particularly important that deduction should not be postponed till after the field work is "completed" and after the field is left. The two processes of observation and deduction should go on together in the field, each aiding the other, if the investigator would avoid as far as possible the disappointment of finding afterwards that the field records are deficient in some particular point where fuller record would have been of critical value in testing a deduction. Memory may sometime supplement written record, but it is notoriously dangerous to trust to unwritten notes. In my own experience, however, careful deduction is more difficult than observation in the field, but it is greatly aided by deliberate thinking and writing while the facts are before the eyes.

Second, it must not be assumed that a theory gains support because its consequences can be definitely deduced. However accurately one may argue out the details of form appropriate to a certain stage in the dissection of a faulted mountain block, the theory of block faulting becomes a demonstrated occurrence only when the sharply deduced consequences of the theory are shown to accord with closely determined facts of observation.

Not only is it important that an investigation should give equal attention to deduction and induction; it is essential to clear presentation that both phases of inquiry should be sufficiently published. It is otherwise almost impossible for the reader to discriminate between sound and unsound conclusions. It is conceivable that an able observer should patiently collect and record a multitude of facts, and that he should very imperfectly set forth the reasons that lead him to the announced explanation of the facts. The hurried reader may in such a case quote the announced explanation and accept it, if he wishes, on the authority of the writer; but the more critical reader will wish to make his own measure of the validity of the announced conclusion, and this he will find difficult in the absence of explicit announcement of the method of reaching it. It is particularly important to consider the deductive side of any problem in which there is substantial agreement among different observers as to the facts directly observable, but in which there is difference of opinion as to the explanation of the facts; for in such a case the correct solution of the problem turns essentially on the validity of the deductions by which the unobservable facts of the past are brought into mental vision.

It may not be amiss to point out that the investigator's effort in all such problems as the one here in hand is simply to supplement the directly observable present facts by the discovery of the unobservable past facts, so that the entire phenomenon shall become known. If observers of sufficient penetration had been present in the Great Basin during all the formative period of each mountain range now seen, their records of unobserved fact might give a complete account of all the processes involved; and it would then be perfectly clear whether the mountain ranges were carved fault blocks or not. In the necessary absence of such observers, we try to replace their records by our discoveries, and although our method of discovery necessarily has recourse to the imagination, the phenomena that we successfully discover are facts of only a slightly different order from those of direct observation. We see certain forms imprinted in stratified rocks, and by reasonable mental process arrive at the conclusion that these are the remains of once living organisms. We see two groups of similar strata in similar sequence, and by reasonable mental process reach the belief that their present discontinuity is the result of what is called faulting. In both these cases, the inferred explanation is accepted by most geologists as of essentially the same order of verity as the observed fact, because it has now stood the test of repeated and minute scrutiny. In the case of the Basin ranges, interpreted as carved fault blocks, many geologists are at present by no means disposed to attach equal value to the existing facts of structure and form reached by direct observation and the supposed past facts of dislocation reached by mental inference. It is therefore appropriate that special attention should be here given to the method of inference by which the past facts are resurrected.

It is the application of the combined inductive and deductive method here sketched, although always applied less consciously and completely in the field than could be wished, that has satisfied me of the essential correctness of the theory which explains the larger ranges of the Great Basin as well-dissected blocks of long-maintained faulting, continued into recent time.

Evidence of Faulting along the Mountain Base. — The first elements for consideration in this problem are those which should, in a type example of a long-faulted, well-dissected mountain block, be expectably associated with the occurrence of a fault along the mountain base.

The simplest and most manifest element of this kind is a nearly straight or but moderately curved base line, Figure 1, passing indifferently across or obliquely along the structure of the mountain mass which rises rather abruptly and continuously on one side, while a sloping plain of waste is spread out on the other. The simple continuity of the base line and the complete absence of rock outcrops on one side of it are essential consequences of long-continued block faulting, and are at the same time not characteristic of any other available geological process. As Emmons wrote nearly thirty years ago, one cannot "imagine an erosion which would leave an abrupt wall of 7,500 feet in height on one side of a valley nearly twenty miles wide" (345). Hence wherever these theoretical consequences are borne out by facts of direct observation, block faulting is thereby given so high a degree of probability while other processes are rendered so highly improbable that the theory of block faulting may be looked upon as well introduced, at least.

The best examples that came under my observation of actual forms which match these preliminary members of the whole series of deduced type forms were not among the Basin ranges proper, but along the bordering Wahsatch mountain front, by which the Great Basin is limited on the east. The mountain base near Provo and near Ogden deserves careful study in this respect.

The Wahsatch range is divided into several local mountain groups by the canyons of streams that rise a number of miles east of the line of higher summits and flow westward to Salt Lake Basin. In the neighborhood of Provo, the canyons are those of Spanish fork, Hobble creek, and Provo river, between which the mountain groups may be called the Spanish peaks, Wahsatch, and the Provo peaks Wahsatch, or more briefly the Spanish and the Provo Wahsatch (Emmons, 340, 344).

Close by Provo, where my party had the most leisure for attention to this problem and where we had the advantage of guidance by Prof. E. H. Hinckley of the Academy in that city, the expectations of theory are extraordinarily well supported by the facts. The mountains spring boldly from the plain; their base line breaks obliquely across the tilted and folded rocks of the mountain mass: the occurrence of a base-line fault is explicitly stated by Emmons (345). Views of the Provo Wahsatch from the roof of the Academy in Provo looking northeast and southeast are given in Plate **4**. We made an excursion up Rock canyon, Plate **4**, A, to a mid-monoclinal ridge back of the frontal summits, and returned by Slate canyon, Plate **4**, B. There are some indications of faults in the longitudinal valleys between the monoclinal ridges (Emmons, 345, 348), but nothing at present known serves to give date to these faults, should they be proved to occur. Figure 4 shows the generalized structure thus determined: an anticlinal axis lies near the western base of the mountains opposite Provo, while a great monocline, the eastern half of the incomplete anticline, constitutes the rest of the range. Further south, the anticline is not seen at the mountain base. The rocks in the anticlinal axis are said to be mid-Palæozoic; those of the crests are Carboniferous (Emmons, 345, 346); further east the maps of the 40th Parallel survey indicate Mesozoic strata. West of the mountain base, no rocks are seen in place; the gravel beaches and deltas of Lake Bonneville descend to the alluvial plain that slopes under the shallow waters of Utah lake.

About twelve miles southeast of Provo, the Spanish Wahsatch, lying next north of Spanish fork canyon, is even more emphatic in its testimony for block faulting. A view along its base is given in Plate **1**, B. Its rock layers are nearly horizontal or dip gently eastward. Some significant details of its form will be considered later.

The Wahsatch near and northwest of Ogden presents several significant features, even when seen only from a railroad train. Its base line is here of moderate curvature, and manifestly traverses various structures, as indicated both by form and by color. The mountain front rises abruptly and continuously from the base line, except for brief interruptions in narrow-mouthed canyons.

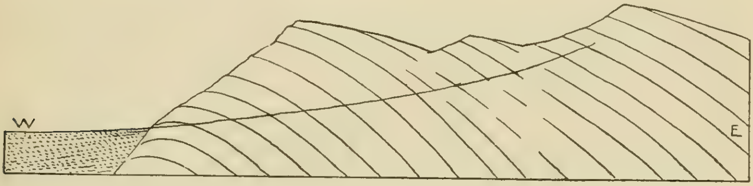

FIGURE 4.

Rough cross-section of the Provo Wahsatch, looking north.

The features of this range and of several others further west, as seen from the passing train, were so accordant with the features more deliberately observed near Provo that the burden of proof seems to me to rest with those who regard the ranges as other than carved fault blocks; but while observations from a train may have a high value to the observer, I am well aware that they will not be regarded as convincing by others, especially not by those whose habitual work in palæontology, petrography, or minute stratigraphy has given them no acquaintance with the value of large elements of form in physiographic problems, even though these elements be only hastily observed from a car window.

During a stage ride northward from Winnemucca, Nev., into southern Oregon, I passed the Santa Rosa and Pine Forest ranges, both of which exhibited very clearly the gently curving base line, regardless of rock structure, and the bold mountain front, continuous except for sharp-cut canyons, that are essentially characteristic of carved-block mountains.

The western face of Jackson range near its northern end had the same appearance, but this was very imperfectly seen. Further details concerning the first two of these ranges are given in a later section. Examples of sloping waste plains in front of dissected ranges are given in Plate **2**, while the linear front of the Pueblo range is illustrated in Plate **3**, A.

The Base Line of Residual Mountains. — It may be worth while to state at this stage of the discussion the reasons for rejecting the theory that the mountain ranges just described are the residuals of much larger masses, of which the vanished parts have been removed by erosion. These reasons are found, not at all in the incompetence of erosion to wear away mountains, but in the impossibility of explaining the forms of the mountain ranges above-named as the residuals of much larger masses. There are numerous examples in which the general subaerial erosion has sufficed to remove mountains more or less completely, but no examples in which the residuals of half-consumed mountains exhibit the features above described as characteristic of certain Basin ranges. Several special cases may be considered.

The only residual mountains known to physiographers as having a relatively continuous mass and rectilinear base are those in which structure controls form, as in the stratified Appalachians of Pennsylvania and Virginia. There the ridges of resistant sandstone rise between rolling lowlands of weaker strata; the ridges are occasionally cut through in water gaps, but between the gaps they frequently present a continuous mass sloping evenly to a nearly rectilinear base. When the strata bend, the ridges turn: when the strata are cut off by a fault, the ridges end. Structure is perfectly expressed in form. The same rule applies to the trap ridges of the Triassic areas of Connecticut, New Jersey, and Pennsylvania; but the rule clearly enough does not apply to the Wahsatch mountains and the other Basin ranges above named.

Residual mountains whose survival is not dependent on contrasts of rock resistance so striking as those of the Appalachians, and whose structure is relatively massive, are well illustrated in the crystalline Appalachians of North Carolina and Georgia. In mountains so old as these, it is to be presumed that the valleys have generally come, by a process of long-sought adjustment, to follow the somewhat weaker rocks, while the mountains represent the more resistant masses. None of these mountains, however, have a bold descent to a nearly rectilinear base; all of them give forth spurs which as a rule slope more and more gradually as they fade away on the valley lowlands; while branch valleys enter between the spurs far into mountains. The mountain base line is sinuous and ill-defined.

One of the most remarkable of these many residuals is a group of radiating spurs that culminate in Big Bald mountain in the older Appalachians of northern Georgia (Ellijay map sheet). The spurs have a notably stellate arrangement between open centrifugal valleys, showing that the mountain is to-day the mere skeleton of a once much larger body; its emaciated form is highly suggestive of the gnawing erosion which it has so long suffered.

A good example for contrast with the Basin ranges is found in the strong east-facing escarpment known in northern North Carolina and southern Virginia as the "Blue Ridge." The escarpment, AB, Figure 5, is evidently retreating westward, for it is simply the headwater slope of the short-course Atlantic rivers, which are actively capturing drainage area from the higher-lying headwaters, AD, of the much longer rivers of the Mississippi system. Viewed in a very general way, as on a small scale map, the base of the scarp is of moderate curvature, and its slope is essentially independent of structure; hence in both these general features it might be said to resemble the face of a Basin range. But when viewed in detail, the base of the escarpment is sinuous in a high degree, with numerous branching spurs that advance between well-carved amphitheaters; the spurs gradually fade out forward, instead of

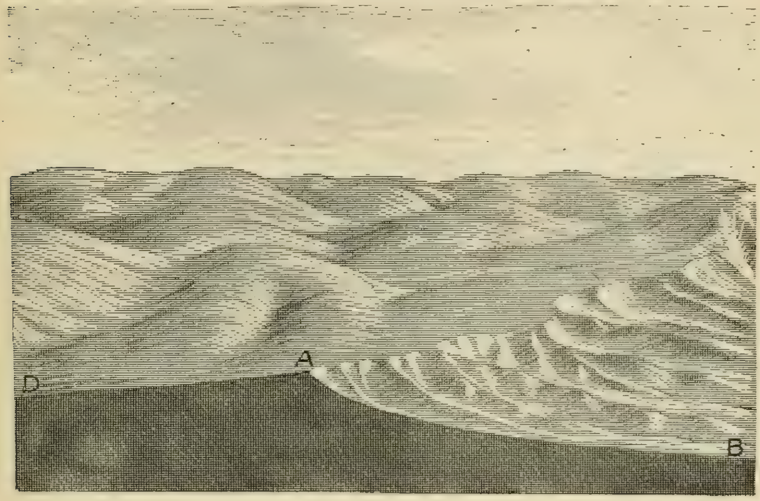

FIGURE 5.

Diagram of the Blue Ridge escarpment, North Carolina, looking north.

being abruptly terminated at a well-defined base line, as is so persistently the case with the above-described ranges of Utah and Nevada. In some cases the spurs run far forward, forming ridges of undulating outline by which embayments of the piedmont lowland are divided. The contrast of the Blue Ridge escarpment and the Basin ranges is therefore extremely instructive. The topographical maps of the North Carolina mountains are worth examining in this connection: Wilkesboro, Cranberry, Mt. Mitchell, and Pisgah (N. C.), and Hillsville (Va.) sheets afford the best illustrations. Some account of their peculiar features is given in a recent essay by the author (1903).

The only conditions under which residual mountains have a well-defined, moderately curved base line is where they are cut across by a master river, or laterally attacked by the waves of a vigorous sea; but these conditions are so manifestly inapplicable to the region of the Basin ranges that they need no consideration here, except in so far as they suggest that a trenchant cause is needed to explain the well-defined base line to which the ranges descend.

Residual Mountains in the Great Basin. — There are, however, some excellent examples of residual mountains among the Basin ranges. Those that I saw are of much less height than the ranges thus far described. Their forms are thoroughly subdued. They have no well-defined and moderately curved base line, but descend in branching, sprawling, fading spurs, which interlock with broad, flat-floored, branching valleys. The contrast of these nearly worn out mountains with the more vigorous forms previously considered is most striking, yet it is entirely conceivable that the contrast may be due simply to stage of development and not to difference of origin. It has already been shown that the late stage of dissection of a fault-block mountain would, long after faulting had ceased, present essentially such worn-out forms as are here described, for the sharp definition of the base line would be lost after faulting had weakened and stopped. On the other hand, the old residuals of massive mountains of any other kind would also present these worn-out sprawling forms. There are indeed no tests by which the two kinds of old mountains can be easily distinguished.

Several examples of residual ranges in the Great Basin were noted as follows: North of Tecoma, Central Pacific railroad, there are mountains of moderate relief, whose rounded branching spurs descend gradually to low, sprawling, dwindling terminals, between wide-open, waste-floored valleys. The fading spurs and open valleys interlock on a very sinuous line. These well-defined features gain an added value by their contrast with the Ombe and Ute ranges, south and west of Tecoma: both of these are of strong relief, with relatively rectilinear base lines on the sides toward the railroad. Their valleys are steep-sided and narrow-floored, causing but little interruption in the otherwise continuous mountain front. Nevertheless, these higher ranges have been abundantly carved, so that their peaks and spurs preserve no indication of an original block form; and no signs of modern faulting, elsewhere so easily recognizable from the train, were here visible.

North of Omar, there is a typical subdued mountain mass, whose dwindling spurs interlock with open valleys. This example was strongly contrasted with the lofty Humboldt range, south of Wells; here the snow-patched peaks descended by strong slopes to a relatively rectilinear base line on the northwest.

Northeast of Golconda, Nevada, a low range descends to a very ragged base, one of the best examples of the kind that my trip discovered. Its description would involve a repetition of what has just been said for other similar ranges, though the description here might be somewhat more emphatic than before.

The only example of this class which I photographed was a small unnamed range, about forty miles north of St. George, Utah, here reproduced in Plate **7**, B. Its spurs were long drawn out, with concave profiles toward their base; its valley mouths were wide open, holding broad waste-covered slopes. Its base line was sinuous and indefinite, in the strongest contrast to the simple and definite base line of the Spanish Wahsatch, Plate **1**, B.

The Canyons and Ravines of Block Mountains. — If we now return to the consideration of the higher Basin ranges, it seems undeniable that faulting gives a much better explanation of their base line than can possibly be given by erosion. Indeed, erosion can be appealed to for the removal of the missing mountain masses only so long as the processes and results of erosion are looked upon as arbitrary and beyond reduction to those generalizations known as natural laws. The day has passed when this is permissible. Erosion, whether subaerial or littoral, fluvial, glacial, or eolian, proceeds systematically through a series of stages; and while there is still more to be learned than is now known regarding the progress of mountain sculpture, enough is already safely understood to exclude the resort to erosion in general as a ready means of accounting for any desired result. It remains, however, to be seen whether not only the base but the face of the Basin ranges is consistent with the theory of block-faulting. The form of the valleys that are carved in the mountain face will be first considered, and after this the form of the spurs between the valleys.

It follows from the scheme graphically represented in Figure 1, that a very rapid and modern faulting of a very resistant rock mass in a very conservative climate would produce a mountain block having a notably smooth fault-face or escarpment along its front. On the other hand, the gradual and long-continued faulting of a weak rock mass in a destructive climate would produce a mountain block having well-developed ravines and canyons whose erosion had been accomplished during the progress of the faulting. The essential characteristic of such ravines would be a V-like cross-section even down to the ravine mouths; and as long as the uplifting of the mountain block actively continues, the streams that are dissecting it cannot widen their valley floors. Indeed, many of the smaller streams might be unable under such conditions to attain a graded slope even in weak rocks, and their channels would be marked by rapids near the base line of the mountain, where the V-ravine would suddenly open upon an alluvial fan, sloping gently forward to the waste-covered piedmont plain. It is only after faulting has ceased that the streams can advance in an interrupted progress toward mature development and widen their valley floors toward the mountain front; and only after faulting has long ceased can the valley floors be so far developed as to leave nothing but residual skeletons of the original mountain block between them. Variations in rate of faulting and in resistance of rock masses would produce many corresponding variations in ravine forms, many of which may be easily deduced, but none of which demand immediate consideration.

The points that need special emphasis in this connection are that the characteristic form of ravines and canyons, carved in a faulted mountain block during the progress of a long-continued and still active faulting, can be reasonably determined by deduction; that these forms are well specialized; and that their most notable peculiarity is the persistence of a V-section down to the mountain base, where the steep-walled ravine or canyon suddenly opens upon a gravel fan that slopes forward to the wide piedmont plain. For example, the canyon of Plate 5, B, opens on the face of Plate 6, B. It goes without saying that this peculiarity of canyon form is impossible in a residual mountain, carved by the extensive erosion of a once much larger mass, unless the most special conditions conspire to produce it. Such conspiracy is found, as has been said, in the stratified Appalachians, where the belts of resistant sandstone, interstratified with much weaker shales and limestones, now stand in relief as residual mountains in which the streams and rivers have cut sharp V-section ravines and notches. The resistance of the sandstones, on which the survival of the sharply limited mountain ridge depends, is, therefore, also the cause of the narrowness of the ravines and notches cut in it by the streams; and it may be added that the sharpness of these forms is in part due to the relatively recent uplift that the middle Appalachian belt has suffered.

All the higher Basin ranges that I saw in the summer of 1902 are characterized by sharp-cut V-section ravines and canyons, narrow-floored and steep-walled down to their very mouths; typical examples are shown in Plate **5**, from the Pueblo range, described below. All these canyoned ranges are so unlike in structure to the ridges of the stratified Appalachians that it is utterly out of the question to explain the former by the theory that is appropriate for the latter.

Rock canyon in the Wahsatch near Provo, Plate **4**, A, has a narrow gravel plain near its mouth, probably the result of delta building in front of the mountain base during the presence of Lake Bonneville; but after going up the canyon a few hundred feet, its stream is found cascading on the more resistant strata, whose rising outcrops form prominent ribs on the steep canyon wall. The same features are observable in Slate canyon, Plate **4**, B, three miles further south, except that the stream here being smaller, its descent is steeper, and it has accumulated hardly any gravels up stream from its Bonneville delta on the mountain front. The beds of both these streams have a rapid descent, and are not cut down as low at the canyon mouth as might be expected in view of the much lower level of the broad piedmont plain a little way forward from the mountain base. Some detention of their down-cutting must be ascribed to the temporary rises of the local baselevel during Bonneville time, and to the work of removing high-level delta gravels in post-Bonneville time; but this cause of detention does not seem nearly sufficient to account for the height of the stream beds over the plain. Hence not only the steepness of the canyon walls, the narrowness of their floors, and the rapid descent of their stream, but also the relatively high level of their mouths suggest recent uplift of the mountain block.

The general form of these two steep-walled canyons suggests not only that the up-faulting of the mountain block has been continued into relatively recent time, but that the uplift of the block by an amount equal to the height of the summits over the base (in the Provo Wahsatch) has been accomplished since the latter part of Tertiary time. The canyons have a much younger expression than that of the narrow valleys in the uplands of southeastern Pennsylvania, for there the streams have formed narrow flood plains and the valley sides are for the most part smoothly graded even in crystalline rocks; yet the elevation of these uplands is not of remote date. If it is thought unsafe to make a comparison between canyons in the arid interior basin of Utah and young valleys in our better-watered Atlantic slope, the Wahsatch canyons with their perennial streams may be compared with the dry side canyons of the Colorado canyon in Arizona. The expression of the two is much the same, allowance being made for the unlike attitude of the rocks. The chief difference between these two groups of canyons is this: those of the Arizona plateaus were cut down in a rising plateau mass by intermittent wet-weather streams working with respect to the sinking local baselevel, the intrenching Colorado; those of the Wahsatch were cut down in a rising mountain mass by more persistent streams working with respect to a relatively fixed local baselevel. The erosion of the Arizona canyons, trunk and branch, cannot have been begun earlier than the latter part of Tertiary time; the erosion of the Wahsatch canyons may well have had an even later beginning. The date assigned to the Wahsatch fault by King, on incomplete geological evidence, is the close of the Eocene; but this seems inadmissibly early in view of the sharpness of the Wahsatch peaks and spurs and of the enormous amount of erosion accomplished in the plateau province in post-Eocene time.

It should be noted, however, that certain through-going streams in the Provo district have valleys that are more maturely opened than the canyons just considered. The so-called canyons of Provo river, Hobble creek, and Spanish fork are all relatively open, with moderately steep, frequently graded side, slopes. This seemed to me in part due to the occurrence of weaker rocks where the through-going streams have cut down their valleys, but I am not sure that this explanation applies in all cases. It may be that in some examples the more open valleys are connected with differences in the date, amount, and rate of faulting. Some of the through-going valleys are nevertheless of true canyon-like form: such is Weber canyon, which is followed from the east by the Union Pacific railroad into the Great Basin at Ogden; and also Ogden canyon, a few miles further north, if the maps may be trusted.

The part of the Wahsatch range next north of Spanish fork canyon, here called the Spanish Wahsatch, Plate 1, A, is beautifully carved with sharp ravines which preserve their narrow floor and steep walls directly to the mountain base. Two of these ravines were visited. The beds of their wet-weather streams pitch forward at an angle of from 22° to 34°, steepening near their mouth; the slope of the side walls is 30°. All the ravines open close to the level of the Bonneville beach, instead of being cut down nearer to the level of the piedmont plain; as in the Provo Wahsatch, this peculiar relation should be here also at least in part ascribed to the recent up-faulting of the mountain block.

The Wahsatch range has many other canyons and ravines of similar form, so far as observation from the plain in front of the mountains can determine, and so far as description by local observers testifies.

The southwestern slope of the Santa Rosa range north of Cane spring deserves further statement. I had time to examine its general features from a spur next south of Cane spring, whence the mountain front was seen somewhat to the right of the view shown in Plate 2, B. The strike of various ledges outcropping on the bare mountain flanks was in general northeastward; that is, about at right angles to the trend of this part of the mountain base. The dip of the ledges was steep southeast, or nearly vertical. Rock structure was, however, very faintly exhibited as a rule; the mountain mass is for the most part worn to the stage of smoothly graded summits and spurs, whose graceful forms were beautifully brought out in late afternoon light. The spurs terminate in strong slopes, sometimes maintaining convex longitudinal profiles almost to their base. The valleys and ravines are steep-walled and narrow-floored to their very mouths. The mountain base is of long and gentle curvature, here convex to the southwest. Faint scarps in the washed gravels close to the mountain base were seen at several points, and were noted as indicating modern faulting. The gravel wash extends far forward on an even slope, thus suggesting a vigorous discharge of waste from the mountain valleys. For several miles east of Cane spring, the strong wash from the mountains on the north meets a much weaker wash from a series of low spurs on the south; these spurs descend gently, some reaching further forward than others, and all blending by gradual concave slopes with the inclined gravel plain before them. So distinct a contrast between the forms of the mountains on the north and those of the spurs on the south must have a meaning. No meaning seems so probable as that which associates the mountain with strong block faulting and active carving, both continued into recent time, and the spurs with a long period of undisturbed erosion.

As a characteristic of this arid and thinly settled region, note may be made of the fruit ranch of a Basque at the mouth of one of the valleys in the Santa Rosa mountains. The small stream from the valleys supplies water enough to irrigate an orchard of a thousand apple-trees and some alfalfa fields: the alfalfa serves for local needs; the fruit is sold to neighboring ranches and villages. Another valley supplies water for some alfalfa fields belonging to the ranch at Cane spring. This spring itself seems to rise where the long wash slope from the mountains on the north comes against the rock that descends from the spurs on the south. Every drop of water available in the growing season is used. Storage reservoirs in the mountains would increase the summer supply, but such reservoirs would be so soon filled with waste — should they indeed escape destruction by a cloud-burst torrent — that the cost of their construction would, it is to be feared, never be repaid.

The Mountain Face. — The study of mountain morphology is so little advanced that one encounters difficulty both as to method and terms in attempting to present a definite account of mountain forms. It is evident, however, that the face of a range, carved on the fault scarp of its tilted or lifted block, should present certain features characteristic of such an origin, and that these features should be deduced as carefully as any others in the mental construction of the type example, so that their occurrence or absence in actual ranges may be determined. In no other way can it be ascertained whether the face of the range as well as its

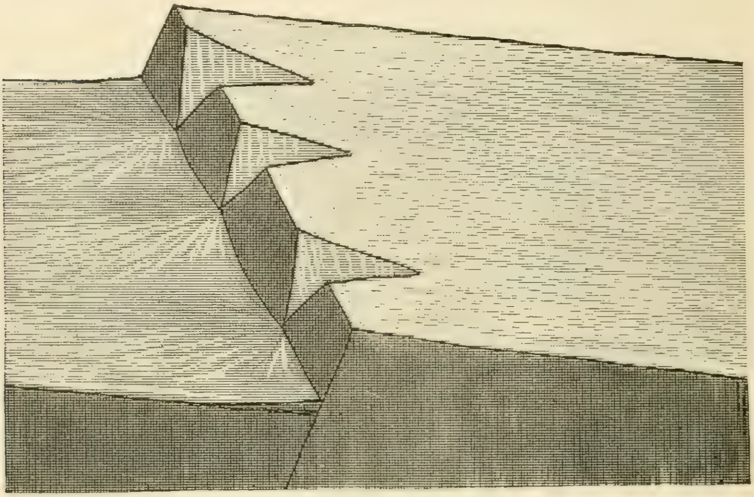

FIGURE 6.

Diagram showing notches in the front of a young tilted block; some of the front edge of the block still remains.

base and its canyons testify in favor of block faulting. The next following paragraphs therefore attempt to discover the forms that should characterize the ideal case of a faulted block of homogeneous structure whose faulting has progressed at a slow and relatively uniform rate, so that the sides of the ravines that are eroded in it shall be weathered back to graded slopes about as fast as the fault block is raised. Three significant stages of faulting and erosion may be considered. In an early stage, Figure 6, the low fault scarp is notched by ravines whose location and length are determined by the site of prefaulting inequalities in the upper surface of the block. Adjacent ravines have not yet widened sufficiently to consume the edge at the top of the block between them. In a later stage, Figure 7, the block is raised higher, the ravines are worn deeper and further back, some of them being larger than others. Noth-

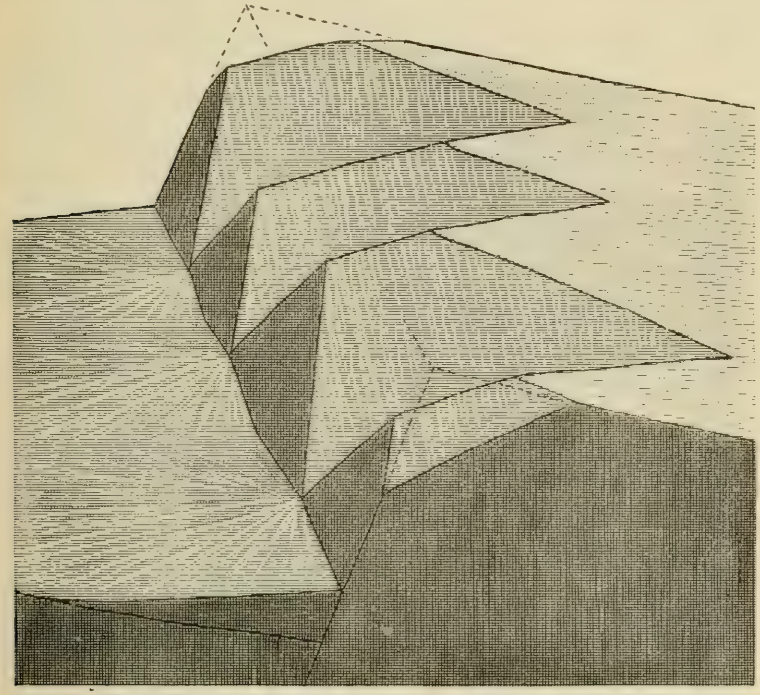

FIGURE 7.

Diagram showing notches in the front of a young tilted block, more uplifted than in Fig. 6; nothing of the front edge now remains.

ing of the upper front edge of the block now remains, for the flaring walls of the ravines now meet in a sharp ridge crest that rises backward from the vertex of a triangular facet on the block front, toward the top of the block. In the third stage, Figure 8, the block is raised still higher, and the ravines have become still longer and deeper; at this stage the mountain crest might become serrate, and its back slope would be well dissected. The long sharp-crested ridges between the larger front ravines are still terminated by triangular facets, very systematic in form and position, with their bases aligned along the mountain front. The spur sides and the facets themselves will have

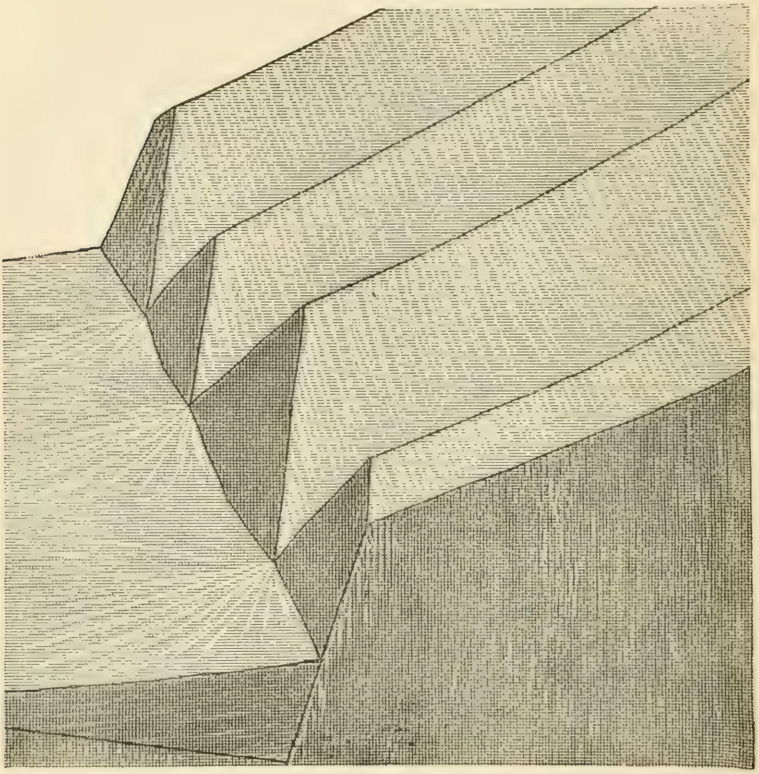

FIGURE 8.

Diagrams showing spurs and deep ravines in the front of a tilted block, uplifted so high that nothing of the upper surface is here seen.

suffered some carving, as is shown in Figure 9, where some of the terminal facets are enlarged. The moderate dissection of the large facet by small ravines results in the development of several little basal facets along the fault line, where they form the truncating terminals of several little spurs. These basal facets are of importance in this stage of dissection, for they have suffered the least change of any part of the mountain front.

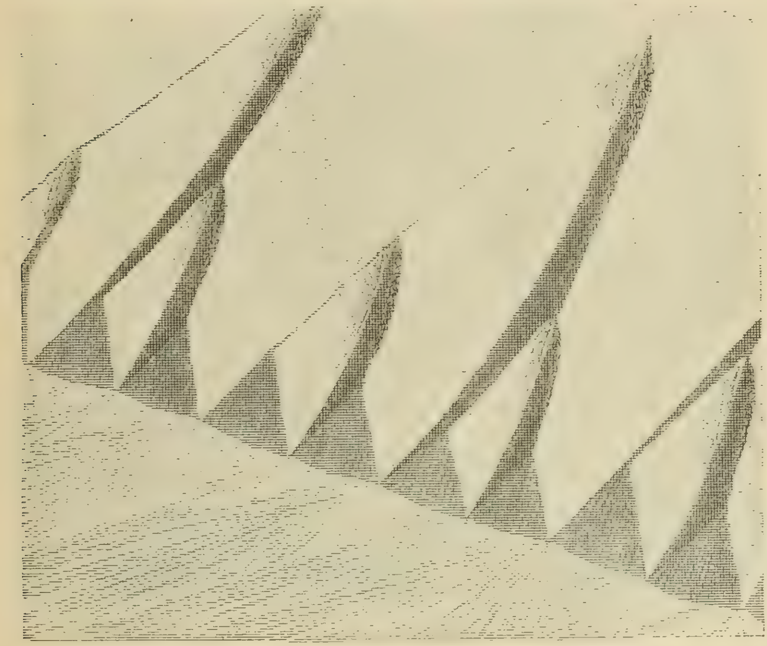

FIGURE 9.

Diagram of dissected terminal faces of main spurs, showing small basal facets between short ravines; drawn on a larger scale than Figs. 6–8.

We are thus led to conclude that the features of special significance as the necessary result of long-continued faulting, persistent into the recent period, are: first, the sharp-cut, narrow-floored valleys which have already been considered; and secondly, the large and small terminal facets of the spurs, whose bases show a notable alignment all along the mountain front.

If faulting be supposed to cease after the stage of Figure 8 is reached, the valleys will widen without much deepening at their mouths, the spurs will be narrowed, and the truncating terminal facets will in time be so far consumed that the spurs will become pointed, as in Figure 10. The further erosion progresses into maturity, the farther will the points of the wasting spurs withdraw from the fault line, and the more perfect will be the relation of structure and form; but as old age is reached this relation is more and more suppressed. It is evident that late maturity or early old age will introduce the system of interlocking valleys and spurs already described as characteristic of subdued residual mountains.

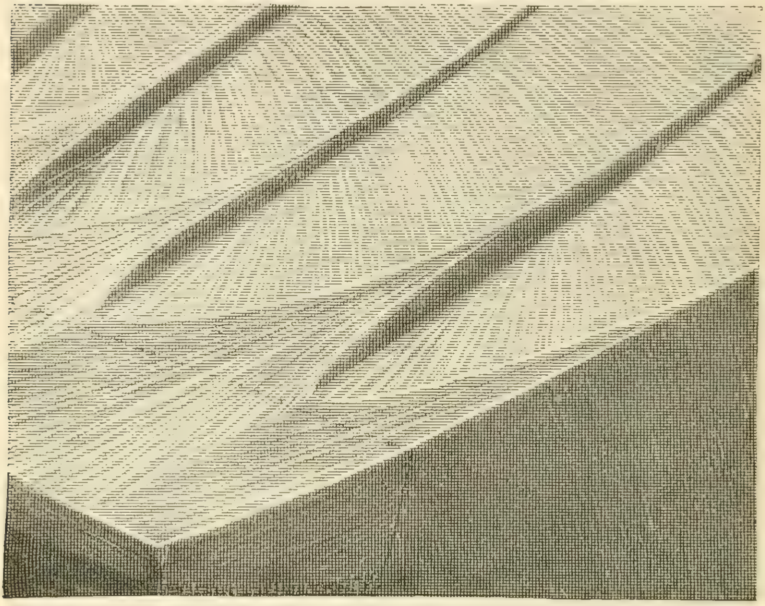

FIGURE 10.

Diagram of tapering spurs between open valleys in a late mature stage of a tilted block; same scale as Figs. 6–8.

Spurs and Terminal Facets of the Wahsatch Range. — The Spanish Wahsatch, opposite the villages of Springville and Mapleton, presents a group of forms that resembles to a singular degree those represented in Figures 8 and 9. The mountain base has already been referred to as shown in Plate **1**, B, an examination of which will now discover the profiles of a series of basal spur-facets, sloping at an angle of 38° or 40°, and possessing remarkably systematic forms which correspond closely to those deduced for the ideal type in its maturely dissected stage. A front view of the facetted spurs is given in Plate 1, A. The ridge or crest line of the spurs slopes at angles that do not vary greatly from 25°. Figure 11, enlarged from photograph and sketch, presents a more detailed view of this part of the Wahsatch, in which the sharp-crested ridges, with their peculiarly systematic terminal gullies and facets, rise between the sharp-cut ravines of the mountain front. The difference between these beautifully sculptured forms and the more rigid diagrammatic features of Figures 6 to 10, is not a difference of kind, for every element in the ideal view is matchable with a corresponding element in the actual view; it is rather a difference due to the occurrence in nature of innumerable little irregularities, the result of slight variations of rock mass and of sculpturing process, whereby actual mountains depart in so pleasing and graceful a manner from the hard and conventional lines of diagrams. In spite of these differences, the notable characteristic of this part of the Wahsatch front is its model-like form, every element of which is so systematically arranged that it can be understood: and thereon depends much of its attractiveness. The expression of its features is open and frank, without that complication of unresolvable elements which makes the meaning of larger mountain forms so difficult of full understanding. One reason for the simplicity of form here exhibited is the simplicity of rock-structure in the mountain block. The strata of which it is built lie nearly horizontal in the district that we examined, and none of them are sufficiently unlike their neighbors in strength or weakness to determine the occurrence of strong cliffs or benches. There

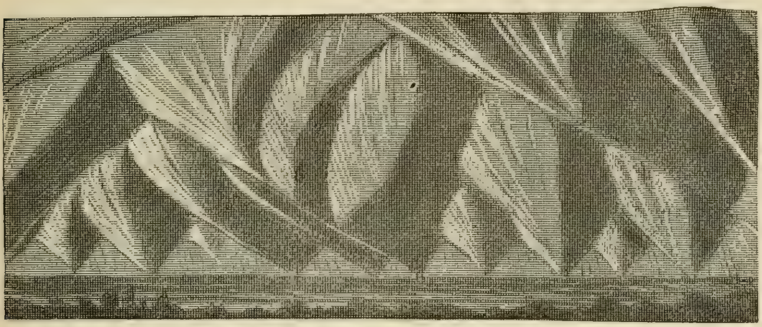

FIGURE 11.

View of the ravines, spurs, and terminal facets of the Spanish Wahsatch, looking east; drawn from sketch and photograph.

are indeed several delicately embossed contouring lines on the spur slopes by which the structure of the mass is indicated in the distant view; and on climbing the slopes there are abundant small outcrops by which the inference from the distant view is confirmed; but as a whole the slopes are graded and cloaked with a thin cover of creeping waste, so that the observer's attention is not too soon diverted from the study of mountain sculpture by an emphatic exhibition of mountain structure.

I first saw the spurs, facets, and ravines of this mountain front from the passing excursion train of the International Geological Congress in 1891; but they were then only regarded as "peculiar." They were seen a second time on returning from a Colorado canyon excursion in 1900, and on that occasion, although they were then again observed only from passing trains northward on one road in the morning, and southward on another in the afternoon, the possibility and necessity of explaining them as a result of erosion on a faulted block was recognized. During the summer of 1902 my party made a special visit to these significant spurs, walked along their base for a short distance, ascended the slope of one of the facets, and came down again by the ravine alongside of it. There seemed to be no escape from the conclusion that extensive and recent faulting of the mountain block is here indicated, not only by the complete absence of the mountain rocks west of the almost rectilinear base line, as already set forth, but also by the detail of form on the mountain face, and particularly by the well-defined facets in which the spurs terminate.

The late afternoon view of the Wahsatch range from the shore of Utah lake brings the mountain forms clearly forth. The eye, after wandering along other less intelligible parts of the range, turns repeatedly to the block north of Spanish fork canyon with enjoyment of the fuller meaning found there. Elsewhere one's curiosity is excited; there it is satisfied. After the sharply defined terminal facets of the mountain spurs are found to be systematic elements of form in the Spanish Wahsatch, they may be recognized in many other parts of the range, but nowhere, so far as I have seen, with the model-like distinctness of development that is exhibited in the example just described.

When the Wahsatch near Provo is seen from a point not too near its base, several spur-facets may be distinguished between the canyons and ravines by which the mountain front is scored; but the edges of the facets are dull, like the edges of a crystal of apatite. In the Spanish block, the sharp-edged facets tempt one to sketch in outline: in the

Provo block, it is by no means so easy to do justice to the mountain form in an unshaded drawing. One reason for this is that the ravines here are not very deeply carved — except the larger ones, called canyons, whose streams head in subsequent valleys back of the frontal ridge — and hence the spurs do not stand forth between the ravines in strong relief. Moreover, accompanying and perhaps causing this loss of definition in the spurs and facets, there is an increased variety of texture in the rock mass, whereby certain resistant strata stand forth bare and prominent between weaker neighbors ; the attention is thus involuntary somewhat distracted from sculpture and turned toward structure. The facets are nevertheless undeniably present, and in essentially the same relation to spur and base line as is shown in the type diagram, Figure 8. The southern end of the Provo block possesses the most distinct examples, some of which will be described in the following section.

The Wahsatch spurs that descend near Little Cottonwood canyon, between Provo and Salt Lake, are systematically terminated by clearly recognizable facets.

The Ogden Wahsatch also offers illustrations of the systematic faceting of its spurs, those adjoining Weber canyon being the most distinct. Further north, back of the city of Ogden, the facets are round-edged, yet distinctly recognizable as systematic elements of form, like those of the Provo Wahsatch.

The spurs of several other ranges, seen from train and stage in Utah and Nevada, were terminated by facets of more or less distinct form. The spurs of the Santa Rosa range were more rounded than many of the others, and the terminal facets were indistinct. The eastern face of Pine Forest mountains in northern Nevada is notably steep and scarp-like, descending to a relatively rectilinear base. The scarp is sharply cut by narrow valleys which remain narrow to their very mouths. Some of the spurs end in rounded facets. Signs of recent faults in the gravels at the mountain base were noted, but at too great a distance to feel certain of their meaning. The height of the range gradually decreases to its trailing southern end. In this range more clearly than elsewhere the narrow valleys seemed to be cut beneath a rolling upland of earlier origin.

The Spur-Facets are not Wave-Cut. — The terminal facets of the Wahsatch front rise over the Bonneville beaches in such a way as to suggest a possible origin as wave-cut cliffs. It is not to be doubted that waves could, if time be allowed, cut off the points of spurs so as to truncate them in triangular facets, but in that case the facets should be associated with certain other features which are significantly absent from the Wahsatch range. This may, as usual, be best demonstrated by consideration of the progress of wave work in an ideal case.

If the surface of a sea or lake should rise on a ravined mountain front, so as to gain an irregular shore line, ABCD, Figure 12, the promontories might in time be cut back to the straight shore line DFH, over which the spurs would then terminate in triangular cliff-facets, DKF, FLH. But in such a case, the valleys should not remain narrow-mouthed during the progress of the wave work, but should widen somewhat and allow the streams to develop flood plains on which they could wander a little; and after the lake waters had disappeared, the facets should look out upon triangular rock platforms, FGH, systematically related in form and area to the facets. As a matter of fact the triangular rock-platforms and the widened valley mouths are wanting in every case that came under my notice. It cannot be supposed that the mountain front was cut back by waves at so low a level that the wave-cut platform is now concealed by mountain waste; for in that case the narrow ravines should also have been cut down to the same low level, instead of opening, as they so often do, rock-floored on the mountain flank, and allowing the streams to continue their descent on gravel fans that rise at the apex distinctly above the intermont plain. One of the best localities for the illustration of

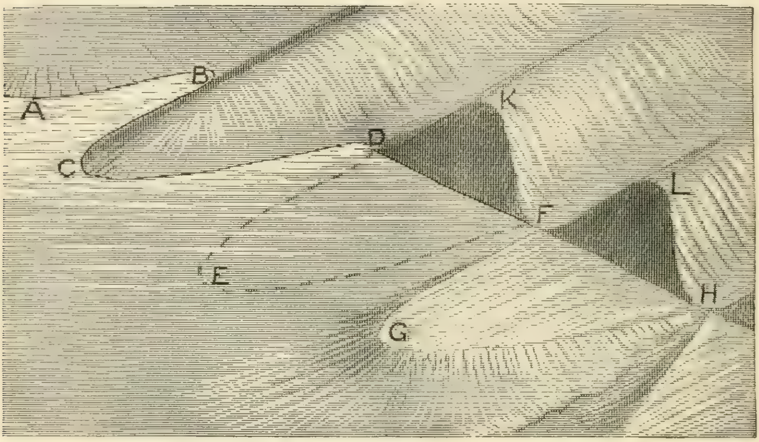

FIGURE 12.

Diagram of spurs cut by waves: ABCD, initial shore-line at time of submergence; DKF, cliff facet cut back in spur DEF; FGH, spur platform fronting its cliff facet FLH, after withdrawal of lake waters.

these features is at the southern end of the Provo Wahsatch, northeast of Springville, Plate **3**, B, where the base line curves from south to southeast. Several ravines furrow the mountain face, dividing it into a number of subparallel spurs, all of which are cut off by rather well defined triangular facets. If these facets are explained as shore-line cliffs, rock platforms should stretch from a quarter to a half mile forward from the cliff base into the plain: but no such platforms are to be seen. If any rock platform exists, it must be supposed that it was cut at a much lower level than that of the Bonneville shore line, and that it is buried under the sands and clays that cover the low ground: but the existence of a wave-cut platform at such a depth is inconsistent with the opening of the ravines in the mountain flank several hundred feet above the plain; the ravines would necessarily have been deepened by their streams as the cliffs and platforms were cut back by the waves; hence the supposition of a wave-cut origin for the facets cannot be favorably entertained: an origin by faulting is much more reasonable. It is noticeable that the stream lines in this part of the Wahsatch pitch with increasing steepness in the narrow gorge-like mouths of the ravines, thus hurrying between a gentler but still steep descent down the ravines in the mountain flank above, and a gentler descent through the Bonneville gravels on the way to the plain below. Indeed, the gorge-like mouths of the ravines seem to be incised somewhat below the base of a series of simply triangular facets, so as to give the spur sections the beginning of a house-end pattern, as if the faulting of the mountain block had been locally accelerated not long ago. The features of this interesting locality would well repay a detailed study.

True wave-cut cliffs and their correlated rock-platforms may, as is well known, be seen at various points on the Bonneville shore line, but the cliffs are usually of much less height than that of the spur-facets in the Wahsatch front; and in no case had the rock-platforms that I saw nearly so great a breadth as would be demanded by the forward prolongation of the facetted Wahsatch spurs so that the slope of the spur crest-line should descend to the platform level. The facets of the Spanish Wahsatch front the basin of Utah lake, not over twenty-five miles broad from east to west: the Bonneville waters here must have been much less powerful than in their more open areas further north; yet these facets are much larger than the true wave-cut cliffs that are seen on more exposed parts of the old shore line. The best facets of the Ogden Wahsatch, above-mentioned as lying close to by Weber canyon, cannot have been much affected by the Bonneville waves, for during much of Bonneville time this part of the mountain base was well protected by the growing delta of Weber river.

The Erosion of the Spur-Facets. — It is evident from what has been said in the section on the mountain face that the retreat of a mountain front from its initial fault scarp will be greater on the stream lines than on the interstream surfaces, and again greater at the apex of a facet than at its base. The concentration of drainage — even if it be only wet-weather drainage — along the stream line of the ravines, and the increase in the volume of the streams from head to mouth has given them strength enough to remove the waste that weathers and creeps down from the ravine walls. There is, however, at present no such concentration of removing agencies along the foot of the mountains; and as the duration of the Bonneville waters at their various levels has been but a small fraction of the whole life of the mountains, it may be said that there has prevailingly been no active agent available for the removal of waste from the mountain base between the mouths of the streams.

If the fault plane were vertical, a large amount of rock waste would have fallen from it, and in the absence of any effective removing agency along the mountain base, some of the waste should accumulate there as a talus, Figure 13, whose foot should advance in front of the fault line. The conspicuous absence of such talus makes it probable that the fault plane was by no means vertical, and suggests that the slope of the spur facets may not be greatly unlike the slope of the faults. In the Spanish Wahsatch, the small facets slope at an angle of 38° or 40°; in the Provo Wahsatch, the slope is from 32° to 38°. Certain ranges in northern Nevada had similarly steep basal slopes.

Other Parts of Block Mountains. — In the early stages of faulting, the back slope of a tilted mountain block should exhibit its prefaulting form little changed, except that all the slopes and streams which had been steepened by the tilting would show signs of more active erosion than the other parts. The lower part of the back slope would be buried under accumulating waste.

In a later stage of faulting, it might be impossible to recognize any survivors of the prefaulting forms, unless near the back base where the small depth to which erosion could penetrate would delay change. The back base line would expectably be much more sinuous than the front base line, for at the back of the range the gravels and sands of the intermont depression would mount obliquely upon a surface in which the inequalities of prefaulting time had been somewhat exaggerated by the revived erosion of the early stages of tilting.

In the early and later stages of faulting, both faces of a lifted mountain block would present features similar to those already described as occurring on the faulted face of a tilted block, while the upper surface of the lifted block would exhibit features dependent on revived erosion, such as are commonly found in uplifted regions. In young blocks of this kind, the intensity of revived erosion would rapidly increase toward the block border; in this respect the upland of a young block would present features very similar to those found in the Arizona plateaus that border on the Colorado canyon, or in the plateaus of western Germany which border either on the Rhine gorge below Bingen or the Rhine graben above Bingen; for so far as the dissection of an upland is concerned, it matters little whether its streams descend by a fault scarp to a lowland or by a canyon wall to a river.

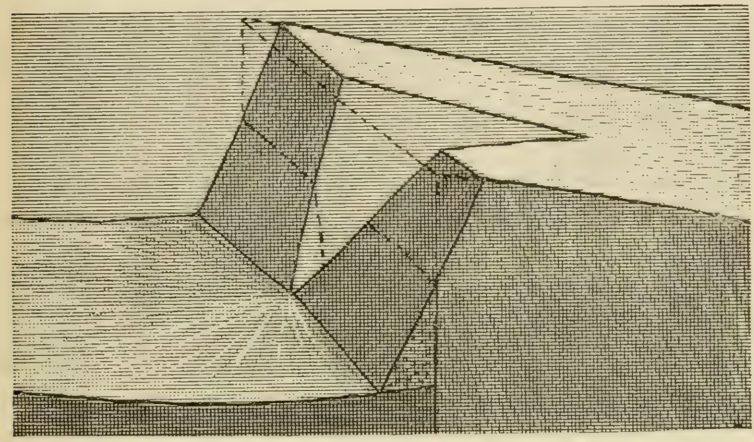

FIGURE 13.

Diagram of talus at the base of a vertical block front.

In older uplifted blocks of longer continued faulting, the contrast of scarp and upland would be weakened; and after the faulting was far advanced, the contrast would disappear entirely. The battered retreat of both scarps, gnawed by retrogressive ravines, would result in transforming the upland into a more or less serrated ridge.

Many special conditions might be imposed upon these general deductions by assuming particular features of prefaulting relief and drainage. These conditions need not be entered upon here, because my observations did not go far enough to provide a large variety of facts with which deductions of specialized types could be confronted. It may be noted, however, that the deduced features of the back slope of a tilted block are not so much unlike the forms of residual mountains as are those of the front of such a block. It is, therefore, not to be expected that tilted-block ranges can be recognized so well when their back is seen as when one looks at their expressive face. But when the features characteristic of the back slope of a tilted block occur on one side of a range while those appropriate to the faulted face occur on the other side, it is reasonable to look upon such a range as the result of block faulting.

The eastern side of the Santa Rosa mountains north of Winnemucca, Nevada, for example, does not imitate the well-defined base line of the western side, so far as I saw this range. The eastern valleys are open and well graded between spaced spurs. The same is true of the eastern base of Jackson range, whose western base has already been mentioned as suggestive of faulting. Moreover, in profile this range resembles a tilted block when seen from the north in such a way that its ravines are hidden behind its spurs. The crest line is near the western side where the slopes are precipitous, while the eastern slopes are much more gradual.

If any ranges have been carved from uplifted blocks, bounded by faults on both sides, they have — so far as the examples that I saw are concerned — reached the advanced stage of dissection in which the initial upland is carved into a serrate ridge. My line of travel seldom made it possible to see both sides of a single range, and hence my notes leave it uncertain in most cases whether a range with a well-defined base line on one side is similarly formed or not on the other side.

Modern Faulting. — It is certainly very significant that indisputable evidence of modern displacement should be found close along certain mountain base lines where abundant evidence of long-continued earlier faulting is provided by the mountain form. This has been so clearly pointed out by Gilbert and Russell that little space need be given to it here. Suffice it to say that repeated instances of scarps in gravel deltas and fans were noted last summer along the Wahsatch base, as well as along the border of certain other ranges to be described below. A distinct scarp in the gravels of the Bonneville beach is traceable all along the front of the Spanish Wahsatch, a little forward from the base of the facets, — Plate **1**, A. The breaks in the delta of Rock canyon creek and in various other gravel deposits near Provo were easily recognized.

It is sometimes suggested that the displacements in the Bonneville gravels are more of the nature of superficial landslides than of deep-seated faults. Taken alone they might perhaps be so considered; but taken in connection with all the associated features they cannot be regarded as independent of displacement in the underlying rock mass.

There is, however, one aspect of the modern faulting that deserves consideration. In all cases that I have seen, the modern movements are so placed that they must be taken as the continuation of long-maintained displacements whose total measure must, as a rule, amount to many hundreds or some thousands of feet. No other explanation has been found for the presence of such mountain masses as have been described above, standing in strong relief on one side of the fault line, while there are only gravels and sands to be seen on the other side. It is, of course, conceivable that modern faulting may have been here and there begun on new lines, essentially independent of the older fault lines, but such cases must be rare; for it is to be expected that, if a modern fault occurs on a new line, it should run across country indifferent to pre-existent structures. Such a fault might run obliquely across an intermont plain, then traverse a mountain range, and continue into another plain beyond the range, the whole length of the fault being marked by a scarp of more or less distinct form. The Great Basin has not yet been carefully enough explored to prove that no such faults occur; but the region is well enough known to warrant the provisional statement that new faults of a date as recent as the scarps of the Bonneville deposits are rare, except in connection with old faults.

On the other hand, there seem to be many ancient faults in the Basin ranges on which movement ceased long ago. This is shown by the obliteration through erosion of relief due to faulting; or sometimes by so great an excess of erosion in the uplifted block over that in the thrown block, that the thrown block now stands above the lifted block, the fault scarp being thus topographically reversed by erosion. Many examples of these kinds are given by Spurr. It does not, however, seem admissible to argue from the absence of modern movement on these faults, or from the apparent absence of modern faults within the ranges, that no long-maintained faulting can have taken place along the range borders. That must be determined by evidence furnished by the borders of the ranges themselves.

The Measure and Distribution of Faulting. — It may be noted that only an incomplete measure of the total movement in block faulting is determined by the difference of altitude between the mountain base and the reconstructed crest in a lifted or tilted block: for in addition to this measure, there must be a certain supplement by which the inequalities of the prefaulting surface have been depressed out of sight in the thrown block. Advanced old age in the prefaulting cycle, and youth or early maturity in the present cycle, are the conditions demanding the least measure of block faulting; for the small relief of advanced old age in the preceding cycle would be consistent with the easy burial of all rock surfaces near the fault line in the thrown block; and youth or early maturity in the present cycle would call for the least addition to the existing height in reconstructing the crest of the mountain block near the fault line.

It is worth while to call attention at this point to a corollary that follows from the provisional conclusion above stated regarding the prevailing absence of modern faults except along the base lines of certain ranges where independent lines of evidence lead to the belief that the modern movements are but the latest displacements on faults of much greater age. The corollary is this: the total displacement on these long-lived faults must be usually greater than the ordinary measure of prefaulting relief in the Great Basin region. For the fault lines must have originally run indifferently to the structure of the region, and therefore indifferently also to whatever relief the region had assumed when the faulting began; and yet the thrown block is now as a rule completely covered with gravels and sands washed from the heaved block. Exceptions to this rule are found at certain points, but they are rare. If further exploration confirm the provisional conclusion above referred to, this corollary may have some value.

In this connection it may be noted that the great measure of displacement inferred by King for the Wahsatch fault (b, 745) seems unnecessary. If the folded strata of the range had been reduced to moderate relief by prefaulting erosion — and this seems not improbable if one may judge by the enormous volume of the Eocene (Vermilion creek) Tertiary to the east (King, b, 745) — the measure of the fault need not be more than enough to raise the crest of the range above the rock floor that is buried under the sediments of the Salt Lake basin; that is, from 6,000 to 10,000 feet instead of 40,000.

It was suggested by Van Hise in the discussion of this subject at the recent Washington meeting of the Geological Society of America that the displacement in faults of large throw, such as those by which the Basin ranges have been formed, are believed to be, is usually distributed on grouped fractures instead of taking place on a single plane of displacement. All the ranges that came under my observation last summer are non-committal on this point, except in so far as the absence of discoverable fractures in the front part of the mountains requires that any additional fractures besides the one which determines the mountain base should be forward from it, and concealed under the gravels of the piedmont plain. Certainly if there are distributed faults in the Spanish Wahsatch block, the displacements on the minor faults within the block must have ceased long enough ago to have been obliterated, so far as surface form is concerned, in the smoothly graded slopes of the spurs; while the movement on the main fault along the front margin of the block has continued to so modern a date as still to have distinct control over the form of the terminal facets.

An article of interest in this connection has lately been published by Mr. D. W. Johnson on block mountains in New Mexico, from which it appears that Sandia mountain, near Albuquerque, is a large block with its chief displacement along the strong escarpment that it presents to the west, but with many smaller displacements within its mass, thus confirming the suggestion of distributive faulting as made by Van Hise. The dynamics of faulting are, however, not yet so well understood that it is safe to assert the occurrence of distributive faulting in all block mountains. Surely no one could have hesitated to believe that the Sandia block was faulted, even if minor faults had not been found on its back slope. In the plateau province of Utah and Arizona several of the greater faults are demonstrably on relatively simple fractures; for the strata of the adjoining blocks come close to the fault line without noticeable disturbance; there is room for fault breccias fifty or one hundred feet wide, but apart from that the faults seem to be for the most part simple and clean cut.

It is evident that the examples of Basin ranges here described are alone too few in number to support any safe conclusion as to the origin of the Basin ranges in general. The Wahsatch range forms the eastern border of the Great Basin province, and although it seems to be of fault-block origin, it cannot be taken as a typical example of one of the isolated ranges within the Great Basin. The chief profit that comes from the study of the Wahsatch range is the definition of certain criteria by which fault-bordered ranges may be determined elsewhere; and this profit will be increased when the back or eastern slope of the Wahsatch shall have been studied in the same relation. The other ranges above mentioned have, however, a certain value in that they were chance samples, not selected beforehand because they were believed to be faulted blocks, but observed as they happened to be passed while the observer was on his way to other points. They thus serve to indicate at least a probability that other ranges in the same region have a similar structure.

The Pueblo-Stein Mountains. — By taking a three-day dusty stage ride northward from Winnemucca, Nev., I was enabled to give a week to the study of the Pueblo and Stein mountains that cross the Nevada-Oregon boundary a little west of the north and south line marked by the post-offices of Denio and Andrews. The stage road carried me past the Santa Rosa, Jackson, and Pine Forest ranges, of which some mention has already been made. The route for part of the distance lay on the dead-level gray silt plain of the extinct Lake Lahontan, whose successive shore lines were traceable at various heights on the enclosing slopes. A long gravel spit, hooked to the east at various levels, stretched northward from the Jackson range to Mason's crossing of Quinn river.

The general result of this week's work gave me the impression that the Pueblo-Stein mountain range is more eroded than would be inferred from Russell's description of it (b, 439,444) ; but there can be no reasonable doubt that it represents a long fault block. The following pages contain a direct statement of the evidence to this conclusion, without analysis of the method by which the conclusion is reached. The analysis has been sufficiently stated in the preceding pages ; its results may now be employed without restatement of the method of reaching them. This is the historical order in the development of methods of investigation, with the time element condensed. When a geologist nowadays describes vertical strata of conglomerate as of sedimentary origin, he does not again go over de Saussure's argument concerning the conglomerate of Valorsine ; when a physiographer now asserts the occurrence of a subsequent valley on the evidence of stream course and rock structure, he need not repeat the argument by which subsequent valleys were first explained by Jukes in the basin of the Blackwater. These are settled questions and may therefore be treated by the short and direct method that steps at once from observation to conclusion. So may the question of block mountains be treated by the short method, provided the complete method has been tried and found valid.

The Pueblo mountains of Southern Oregon, Figure 14, overstep the state boundary at Denio and extend about ten miles southward into Nevada. They trend northward to a high dome 15 miles north of Denio, and then fall off in a broad westward re-entrant back of Doane's and Field's ranches. The high serrated range north of the re-entrant is the beginning of the Stein (or Steen) mountains. The Pueblo mountains consist of two ranges for most of their length. The eastern or front range, Figure 15, is made of ancient crystalline rocks, such as diabases and mica schists. The western or back range is made of bedded lavas, basaltic so far as I saw them, whose westward dip of 15° or 20° is well expressed in a series of east-facing escarpments. Paired wet-weather subsequent streams drain the longitudinal depression between the two ranges, and their gathered waters escape eastward by deep-cut narrow-floored, steep-walled gorges through the front range to the broad plain known as Alvord valley. Russell marks a fault along the intermediate depression (b, 444, Pl. LXXXIV.); but the relation of the western lavas to the older rocks of the eastern range, as seen from the Stein mountains, Figure 16, from Doane's ranch near the north end of the range, and again in the depression between the ranges back of Deegan's, seemed to be best explained by normal superposition of the lavas on the crystal lines, followed by tilting and erosion without faulting. The depression between the front and back ranges is thus to be interpreted as a series of normal subsequent valleys, eroded along the weaker basal members of the lava beds by branches of streams that transect the eastern range and that are probably persistent from an earlier pre-faulting cycle of erosion.

The eastern base of the mountains is, however, unquestionably determined by a fault on which a total movement of several thousand feet has probably taken place, the latest displacements being of recent date, as Russell has shown. The base line of the range is of gentle curvature, indifferent to the structure of the mass. An excellent illustration of this is seen a mile or more south of Catlow's ranch, where a boldly outcropping rib of strong rock, standing oblique to the trend of the range, terminates evenly with the adjoining weaker rocks at the mountain base, and the face of the rib seems much sheared and broken. The ravines and gorges through which the range is drained are steep-walled and narrow to their mouths. The spurs between the ravines are abruptly cut off by the base line, and show no tendency whatever to trail forward into the plain.

Recent faulting along the mountain base is shown by several topographic features. At a number of points near the northern end of the range, between Catlow's and Doane's, open graded valley floors now stand a hundred feet or more above the mountain base, and are sharply trenched by the streams that formerly graded them. Uplifted and dissected fragments of broken fans are often seen one hundred feet or more above the mouth of a gorge, an excellent example of this kind being found back of Denio, while others occur near Catlow's. In general, the summits and higher slopes are of moderate declivity, frequently well covered with waste and exposing few ledges; while the walls of the cross-cut gorges

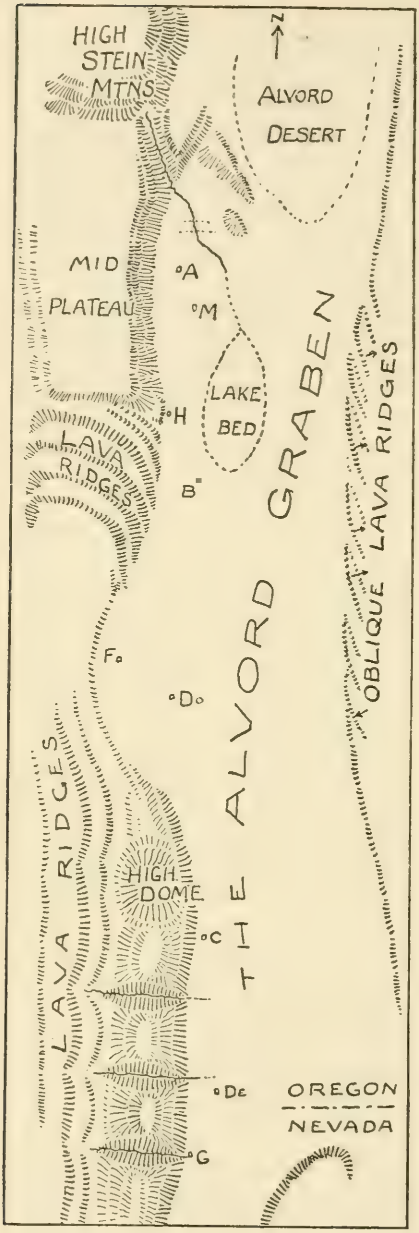
HIGH STEIN MTNS
N
ALVORD DESERT
MID PLATEAU
A
M
LAKE BED
H
LAVA RIDGES
B
THE ALVORD GRABEN
OBLIQUE LAVA RIDGES
F
Do
HIGH DOME
C
LAVA RIDGES
De
OREGON
NEVADA
G

FIGURE 14.

Rough map of the Pueblo and Stein mountains. The side of the map is fifty or sixty miles, north and south. A, Andrews; B, Borax works; C, Catlow's ranch; De, Denio; Do, Doane's ranch; F, Field's ranch; G, Deegan's mine; H, Hollis's ranch; M, Miranda's ranch.

are steep, with abundant ledges, and in some cases the gorge walls steepen as they descend to the stream line. The slopes of the spur profiles commonly steepen toward the front base line; their general descent is at angles of from 10° to 25°; but they often steepen downwards to 30° or 35°. The spur terminals are, however, well rounded, and but faintly recall the sharp-edged facets of the Spanish Wahsatch.

The southern part of the Pueblo range offered the best illustrations that I found of the trailing end of a faulted block, less dissected than the middle part and therefore probably representing a subrecent increase in the length of the block by a southward extension of its marginal fault. The front base of the range is here as elsewhere oblique to the structure; the crystalline rocks disappear first, and the lava monocline continues several miles further south before dying out. The frontal escarpment of the monocline is very straight and but little dissected; the fans at its base are low, and a very gentle slope of alluvium leads from the base line to a dead level playa, half a mile to the east. The lava monocline is somewhat complicated by a transverse fault and a transverse monoclinal fold; but the frontal escarpment pays no attention to these disturbances.

The Stein mountains, Figure 14, continue the general line of the Pueblo mountains, although separated from them by the westward re-entrant already mentioned. The structure of this range is, however, unlike that of the other in consisting almost wholly of lavas for at least as far as some distance north of Andrews. The lavas resemble basalts and andesites, commonly porphyritic. The range may be conveniently described in three parts: the southern part is a warped monocline, dipping south and southwest, and obliquely cut off on the east by the north and south mountain base; the crest of this part of the range is serrated. The middle part is a plateau-like mass, with gentle western dip. The northern part is much higher than the rest; it was generally hidden in clouds or haze during my visit, and its structure was not determined.

I had an excellent view over most of the southern part of the range from the southeast corner of the middle plateau section, whence a great extent of country is disclosed. Alvord valley has every appearance of being a graben, limited by a fault on the east as well as the west; many low ranges trending to the south-southeast are obliquely cut off in a notably even line along the eastern valley margin. To the northeast, an escarpment bordering the valley is banked up with sands blown from the extensive playa of Alvord desert which occupies that part of the depression.

Not only is the Alvord depression seemingly a trough or graben, but the southern and middle parts of the Stein mountains are carved in what seems to be a lifted block, with a fault along the western as well as along the eastern border. The reason for this opinion cannot be presented as conclusive, for it is based only on what was seen from the point of view above named, yet there is little doubt in my own mind of its being correct. The southern and middle division of the range appeared to be evenly cut off along their western border, and this appearance was especially distinct for the southern division where the western border trends nearly square across a series of monoclinal ridges and valleys. The mountain block is ten or twelve miles wide, and is succeeded on the the west by a brown-gray plain, at 1,000 or 1,500 feet lower than the ridges, and 2,000 or 2,500 feet lower than the middle plateau division.

The monoclinal structure of the southern division has a strike in its western part to the west-northwest, with a southerly dip of 15° or 20°. Erosion has developed a number of well-defined ridges and valleys, and the generally accordant heights of the ridges as they rise gradually eastward suggests that the monoclinal mass had been much eroded previous to the uplift whereby the present dissection was initiated. As the ridges approach the crest of the range, which lies about three miles from its eastern base, the strike of the monocline turns to the southeast or south-southeast; the harder beds in the monoclinal ridges rise eastward to form the peaks, while the valleys of the monocline may be traced upward to the notches in the serrated mountain crest. On the eastern slope, the harder beds form benches that descend obliquely southward toward the eastern mountain base, where they are successively and evenly cut off.

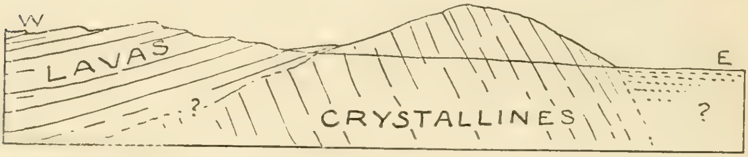

FIGURE 15.

Cross-section of the Pueblo mountains, looking north.

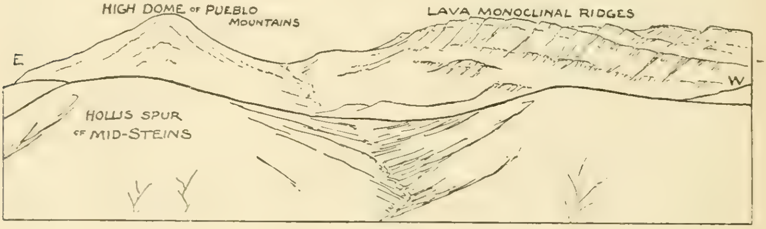

FIGURE 16.

View of the north end of the Pueblo mountains, looking south over the Hollis spur of the Mid-Stein mountains.

This form can be easily explained as a block of a baselevelled monoclinal mass, lifted and somewhat tilted to the west, and maturely eroded; but I find it difficult to explain it in any other way. A subrecent pause in the uplift of the block is indicated by the occurrence of well-defined graded basal slopes, independent of structure, now raised several hundred feet above the Alvord plain and dissected by numerous streams.

During this pause, the definition of the mountain base would have been much less distinct than it is to-day; indeed the base line would have been obliterated along a considerable fraction of the mountain front. Renewal of uplift has made the base line well defined to-day in the southern division of the range, but the streams on the aggraded floor of Alvord valley do not share in the revival by which the same streams on the mountain flanks have trenched the old graded slopes. A considerable period of time must have elapsed since the original uplift of the block began, for the crest of the range is now worn two or three miles back from the eastern base.

The middle division of the Stein mountains, Figure 17, is a monocline of so gentle a westward dip that it possesses a broadly rolling upland surface, limited on the east by the strong escarpment which falls 2,500 or 3,000 feet to the Alvord trough, by a lower escarpment which overlooks the monoclinal ridges and valleys on the south, and by a strong escarpment again on the west. I believe all these escarpments have been worn back from fault lines, and there is some reason for thinking that the fault between the two divisions of the range, trending west-northwest, is older than the meridional faults on the east and west; but I will leave the discussion of this point to some one who can treat it in greater detail. As in the southern block, the crest line of the eastern block is now worn back two or three miles from base, indicating a long period since the block was first uplifted.

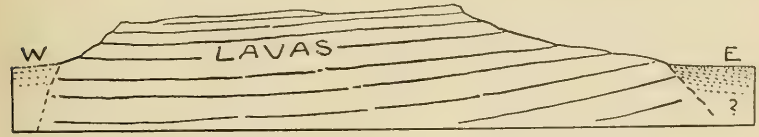

FIGURE 17.

Cross-section of Mid-Stein mountains, looking north.

The face of the eastern escarpment presents many graded slopes between the ledges of more resistant lavas. The spurs between the obsequent ravines by which the escarpment is dissected usually descend with concave slopes toward the plain; but a short convex profile is often seen as the spur reaches the base line. The lower parts of many spurs exhibit well-defined graded slopes on the interstream surfaces, but the spurs are now rather sharply separated by the ravines, and thus indicate a prolonged pause followed by a subrecent uplift.

For the greater part of the range front, the fans that spread forward from the ravines are not faulted, but near the junction of the southern and middle blocks, subrecent and recent faulting is conspicuous. The most interesting locality is near Hollis's ranch, Figure 18. Here several strong bluffs rise rather boldly from the plain, forming terminal escarpments to spurs whose interstream surface, 600 or 800 feet over the mountain base, seems to have been well graded and reduced to small relief before it was cut by the streams that are now eroding sharp ravines in it; but the same streams run forward on aggraded gravel fans east of the mountain base line. The bluffs between the streams occasionally show outcropping ledges, but most of the bluff face is an even slope of slide-rock at an angle near 35°. Just north of Hollis's ranch, the bluff must be nearly 1,000 feet high, but it rapidly diminishes in strength north and south; and a mile and a half or two miles from the highest part of the bluff, the mountain base is of the usual gentle expression. The largest stream that cuts the bluff has a sharp-cut gorge next north of Hollis's ranch, whose irrigated fields lie on the fan that the stream has built. Very recent faulting is indicated by fragments of an older fan, now standing about 150 or 200 feet above the present fan on either side of the canyon mouth. Next north and south there are two "hanging valleys," 500 or 600 feet over the plain, the like of which was not noted elsewhere along the Stein mountain front.

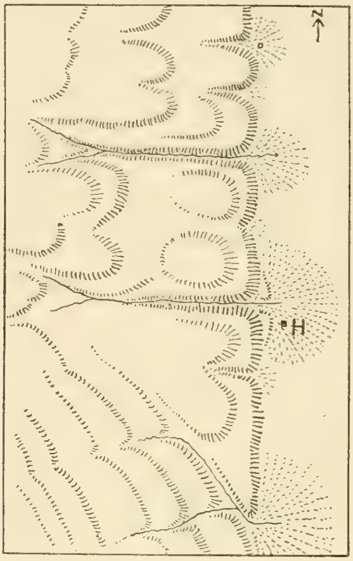

FIGURE 18.

Rough map around Hollis's ranch. The side of the map is five or six miles, north and south.

Some of these local features might be explained, independent of faulting, by the occurrence of a mass of unusually resistant rock at this part of the mountain base; but in that case it might be expected that a greater number of outcrops would be seen on the bluff faces and in the ravine walls. As far as the rock was examined, it seemed to be a porphyritic andesite, similar to other lavas of the mountain block.

Moreover, a mass of resistant rock could hardly be expected to be limited, except by a long block fault, so close to the line of the general mountain front; and it can hardly be a matter of chance that just where the general form of the mountain base suggests the most extensive subrecent faulting, there should occur the strongest recent fault as indicated by a broken gravel fan. Accepting then the conclusion that faulting is responsible for these basal bluffs, it may be noted that they are roughly in the stage of dissection indicated in Figure 6, except that all the edges are rounded off; but the initial upland of Figure 6 is here represented by the graded interstream surfaces that had been worn down to gentle slopes before the subrecent faulting began. There is some reason for associating this renewed uplift with the fault that has been above suggested to separate the southern and middle division of the range; but more detailed field work is necessary on this point.

The northern part of the middle Stein escarpment is breached by a large valley that comes southeast from the high Steins, and a small plateau-like block is thus cut off from the main mass as shown in Figure 14. Several low lava-bed monoclines, of gentle dip to the southwest, extend southeast from the detached block; they gradually dip underground near the southern end of the Alvord desert (playa) and their trend very strongly suggests a connection with the monoclinal ridges of similar strike on the eastern side of the Alvord trough. It is certainly reasonable to infer a fault with downthrow on the southeast between these low lava monoclines and the high detached block that overlooks them.

The Quaternary lake that Russell has described as occupying the Alvord trough left shore lines of moderate strength at various levels up to a few hundred feet over the present lake bed plain. The best examples noted are seen on the low lava monoclines, just mentioned, where faint benches are developed; in the embayment of the main depression that heads between the low monoclines and the main escarpment of the middle Stein plateau, where two cross-bay bars were built to a height of 10 or 20 feet, about a mile north of Andrews; beneath the strong bluffs just north of Hollis's ranch, where shore lines are associated with the chief fan delta of that district; and near the north end of the Pueblo range, between Doane's and Catlow's, where what seems to be a long spit was built out into the lake from the bend in the mountain front near the beginning of the re-entrant between the Pueblo and the Stein ranges.

To any one who wishes to give a month to the study of a well-defined graben, bordered east and west by uplifted and well-dissected mountain blocks, Alvord valley may be highly commended.

The Shoshone Range. — On returning from Oregon, I passed by the northern end of the Shoshone range in north central Nevada in an eastbound afternoon express train on the Central Pacific railroad between Argenta and Shoshone. My notes, rather hurriedly written at the time, are as follows: "A very fine fault block, with manifest recent and subrecent faulting. Broken fans; light-colored basal slopes, ripped with gullies; uplifted grades, truncated spurs, revived streams in full-bodied spurs; spur tops dark gray, sides lighter; tops graded, sides ripped. Even fronted base, facing west and north; all excellent examples for study. At some points on west base, very short fans, as if plain had been depressed."

This specimen of a block mountain interested me greatly. It served as an example for rapid review of many features that I had studied at more leisure in other ranges. It sufficed to show that physiographic evidence of block faulting may be easily and quickly recognized when it is looked for. It confirmed my opinion that such evidence compares well in logical and compulsory value with the stratigraphic evidence on which the demonstration of faulting is usually dependent. It strengthened my belief in the importance and the possibility of describing all land forms rationally and systematically in view of their evolution.

The description of the Shoshone range in the reports of the 40th Parallel Survey is so closely limited to matters of geological structure — as was natural enough at the time the Survey was made, and the reports were written — that no consideration is given to the physiographic features here discussed. The range is not mentioned in Gilbert's or Russell's reports, or in Spurr's essay. The fuller meaning of my notes, supplemented by the maps and reports of the 40th Parallel Survey, and by the thoughts that accompanied the observations, is as follows: —

The northern ten miles of the Shoshone range in north central Nevada is an east-dipping monocline of Weber quartzite overlaid by basalt (40th Par. Surv., map 4, west half). It is bordered on the north and west by the open alluvial plain through which Humboldt river wanders. From five to ten miles north of the range lies Shoshone mesa, composed of rhyolite covered by basalt, fronting southward in a strong escarpment, and dipping gently northward. The Central Pacific railroad skirts the base of the range for twelve miles along its northern end, giving a good view of part of its western outcropping face, and its northern cross section. The range has every appearance of being a dissected monoclinal fault block, owing its relief to gradual and long-continued displacement, whose later movements are clearly recorded in the form of its base. Although the observations on which this statement is made were made only from a passing train, they are believed to be fully deserving of credit. It should be understood, however, that they apply only to the northern part of the range. The passage from observation to explanation may be stated as follows: —

The first feature to be noted is the block-like appearance of the mass, especially as indicated by its basal outline. The base line is relatively well defined, of very small irregularity and of moderate curvature; the basal mass is continuous but for the narrow ravines that divide it into full-bodied spurs.

In the second place, attention should be given to the contrast of the heavy mountain mass and the broad piedmont plain. The lower slopes of the mountain are strong; they change rather abruptly into the broad alluvial plain that stretches away unbroken for several miles. The depression, floored by the piedmont plain and drained by Humboldt river, is five or ten miles wide between Shoshone range on the south and Shoshone mesa on the north, and does not give the impression of being a normal trunk valley, eroded in a once continuous rock mass; for if it were of such origin the branch valleys by which the mountain is drained ought to be of correspondingly advanced development with broad-open floors; while as a matter of fact the branch valleys are narrow to their mouths at the mountain base. Moreover, in the neighborhood of Palisade, twenty-five or thirty miles further east, the Humboldt river has what appears to be a perfectly normal valley; a narrow canyon cut in lavas. The broad plain and the narrow canyon cannot both be parts of an undisturbed normally eroded valley; and as the narrow canyon is manifestly of river origin, the broad depression must be otherwise explained.

The depression might at first sight be regarded as a down-warped part of a normal valley, heavily aggraded with alluvium; but this supposition is untenable, because the alluvium does not invade the ravines on the mountain flank as it certainly should if the ravines had been carved with respect to a now-buried trunk valley. Some other origin than erosion must therefore be discovered for the depression alongside of the mountain.

Differential movement or faulting, the only other conceivable origin of the depression — the supposition that the mountain rocks were originally deposited only on their present limited area need not be considered — is not only permissible by its appropriateness to the outline of the mountain base; it receives strong support from the abundant evidence of the recently continued movement on the fracture by which the depression and the mountain block were originally outlined. The evidence to this end is interesting from its variety and its accordance.

Graded valley floors of moderate width dissect the mountain side, but their floors lie one hundred or two hundred feet above the plain; the valley streams have now entrenched narrow ravines in the valley floors, and thus flow out upon alluvial fans at the mountain base. The spurs between the ravines are of rounded, full-bodied form; they do not taper away on the plain, but are rather sharply cut off by the basal slope of the mountain. The upper surface of the spurs is maturely graded, but their lower slopes are often gashed or "ripped" by little gullies, suggestive of active erosion; the color of the spur slopes is therefore prevailingly lighter than that of the spur tops. Many of the fans are broken by low scarps closely in line with the mountain base; this indicates a continuation of faulting into a very recent period. Some of the fans at the northern end of the western base of the range seem unusually low, as if the plain there had been depressed while the mountain was rising. Taken all together, one can hardly imagine more satisfactory evidence of block faulting.

It should be noted, however, that the higher parts of the mountain seem to have been abundantly dissected since the faulting began. The west-facing scarp of the basalt sheet is now a mile or more back from the west-facing scarp of the underlying strata, but the accordant outlines of the two scarps strongly suggest the original definition of both by the same surface of fracture. Deliberate and detailed study of this range would well repay the observer who could undertake it.

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EXPLANATION OF PLATES.

PLATE 1.

A. The front of the Spanish Wahsatch, looking south. The terminal facets of the spurs are here seen in profile. The Bonneville beach makes a bench at their base, and the beach is broken by a recent fault scarp a little forward from the mountain. The canyon of Spanish fork is in the middle distance, and the Mount Nebo division of the Wahsatch range rises beyond.

B. The front of the Spanish Wahsatch, looking east. The spurs and their terminal facets, separated by sharp-cut ravines, are here seen in full face view. The Bonneville beach is a light line just over the trees of the nearer fields. Plate **1**, A, was taken from the vertex of the triangular facet to the right of the mid-base of the northernmost spur.

PLATE 2.

A. An unbroken fan at the base of the Pueblo mountains. A view down the canyon from which this fan is supplied is given in Plate **5**, B. Deegan's house is close to the mouth of the canyon. The view is taken looking a little west of north.

B. Cane spring ranch and the Santa Rosa mountains. The ranch lies near the Lahontan shore line on the long slope of waste that is spread forth from the mountain ravines.

PLATE 3.

A. The eastern face of the Pueblo mountains. The rounded spurs shown here contrast with the sharp-edged spurs of the Spanish Wahsatch, Plate **1**, B. This part of the range stands between the two canyons shown in Plate **5**.

B. The southern end of the Provo Wahsatch. The mountain spurs are terminated by well-defined triangular facets whose bases stand at the level of the Bonneville shore-line. The view is taken looking northeast.

PLATE 4.

A. Rock canyon in the Provo Wahsatch. The walls of the canyon are more rugged than the front slope of the range. The view was taken from the roof of Provo Academy, looking northeast.

B. Slate canyon in the Provo Wahsatch. This repeats the features of the previous view. It was taken from the same point, looking southeast.

PLATE 5.

A. A canyon in the Pueblo range, near Denio. The view is taken from the lateral slope at the canyon mouth, looking up-stream (west). The broken fan at the canyon mouth is shown in Plate **6**, A.

B. A canyon in the Pueblo range, near Deegan's. This canyon is three miles south of the one shown in the preceding plate. The view is taken looking eastward to the Alvord valley plain. The fan at the canyon mouth is shown in Plate **1**, A.

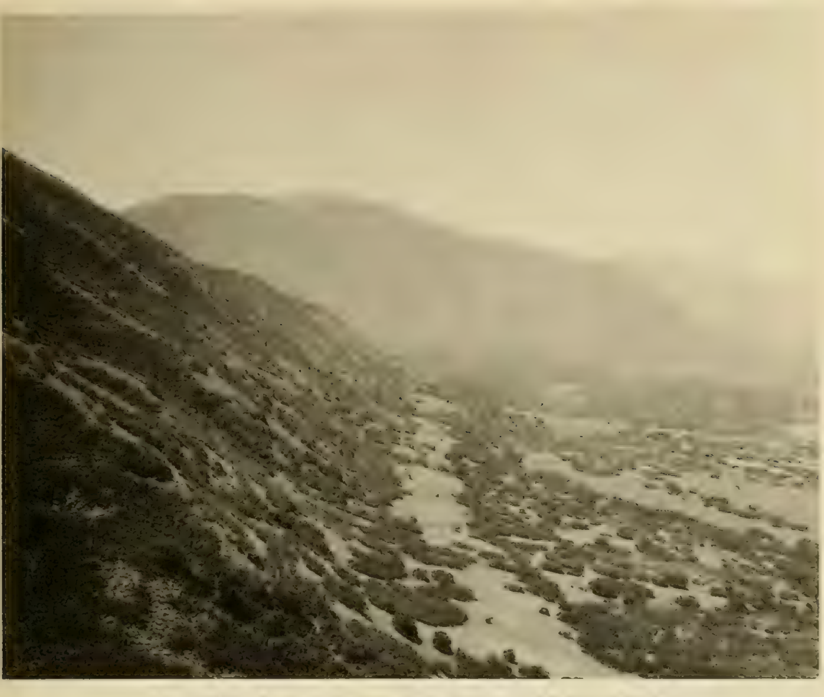
PLATE 6.

A broken fan in the Pueblo range; front view. This fan is at the mouth of the canyon near Denio shown in Plate **5**, A. The direction of the view is northwest.

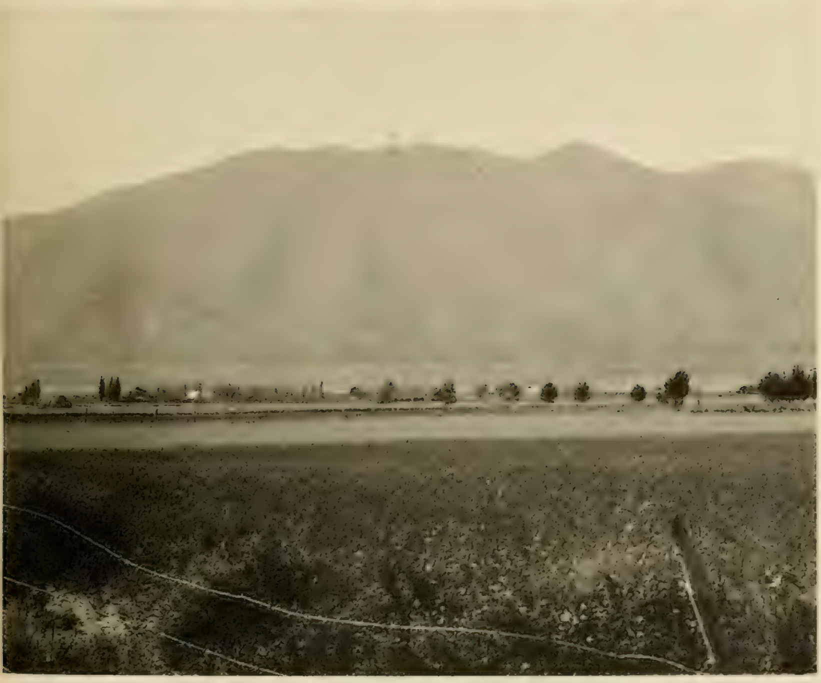
PLATE 7.

A. The Stein mountains, near Andrews. This is part of the east-facing escarpment of the middle division of the range, as seen looking northwest from Miranda's ranch. The base line of the range is here poorly defined.

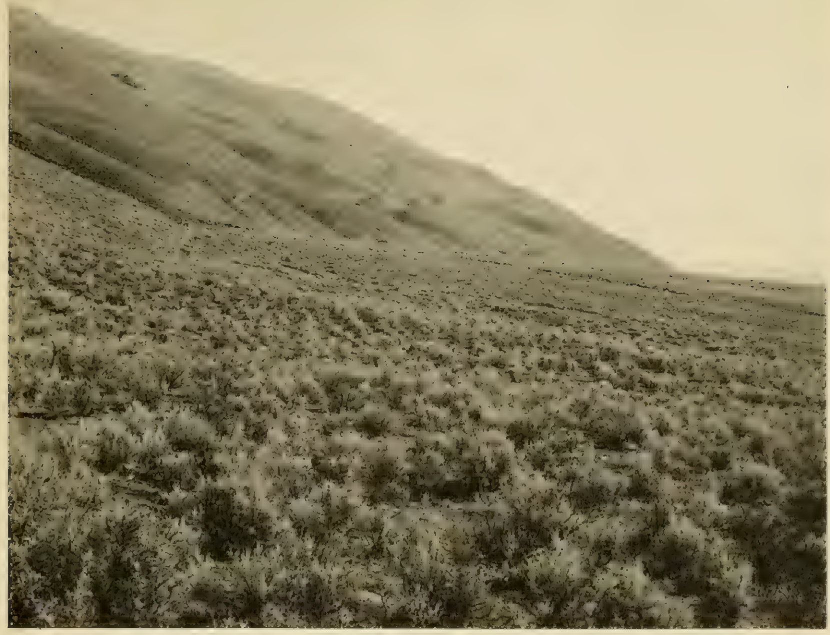
B. A residual mountain range in southern Utah. This small unnamed range, about forty miles north of St. George, possesses gently sloping spurs, open-mouthed valleys, and an ill-defined base line, in contrast with the Wahsatch and Provo ranges illustrated above.



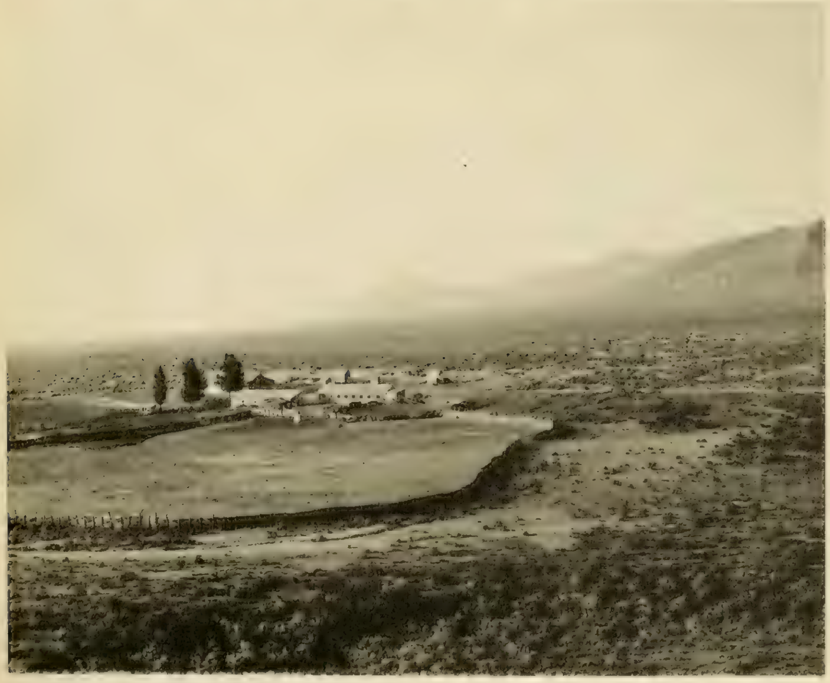
A. FRONT OF THE SOUTHERN WASATCH, LOOKING SOUTH.



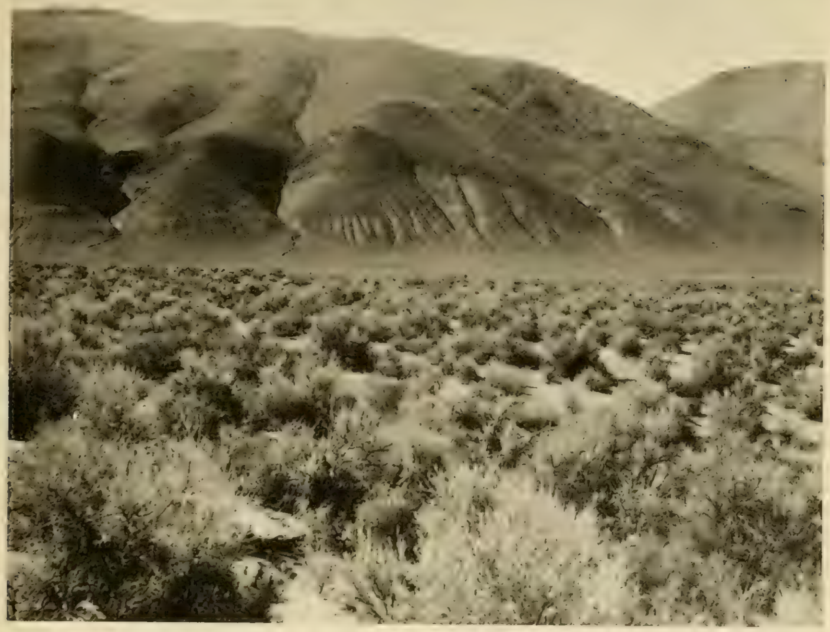
B. FRONT OF THE NORTHERN WASATCH, LOOKING EAST.



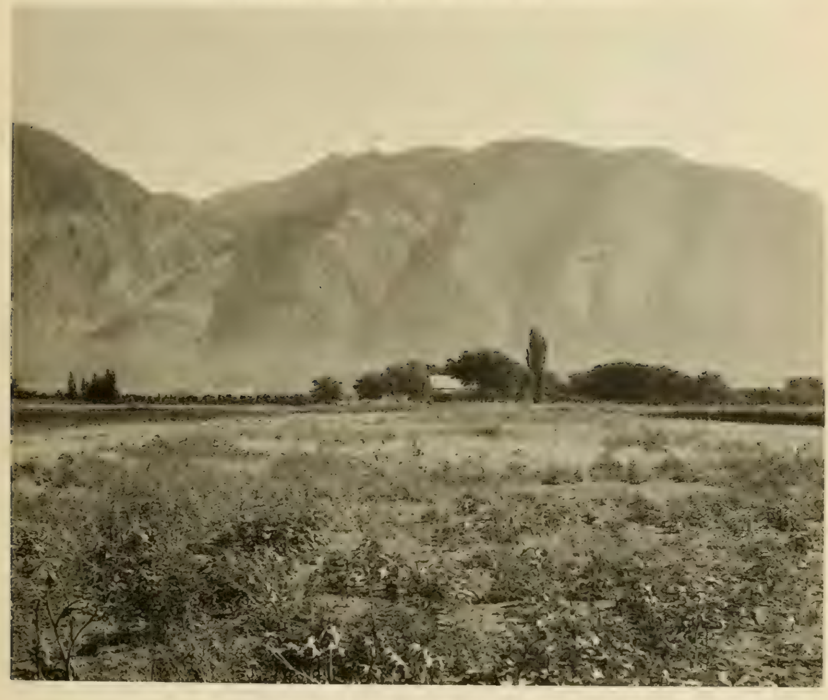
A. UNBROKEN FAN AT THE BASE OF THE PUEBLO MOUNTAINS.



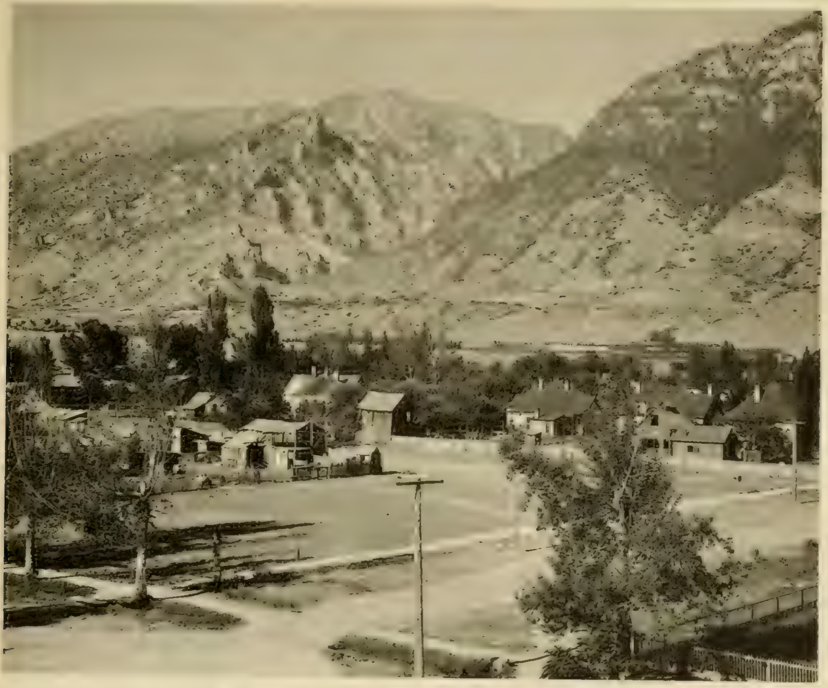
B. CANE SPRING AND THE SANTA ROSA MOUNTAINS.



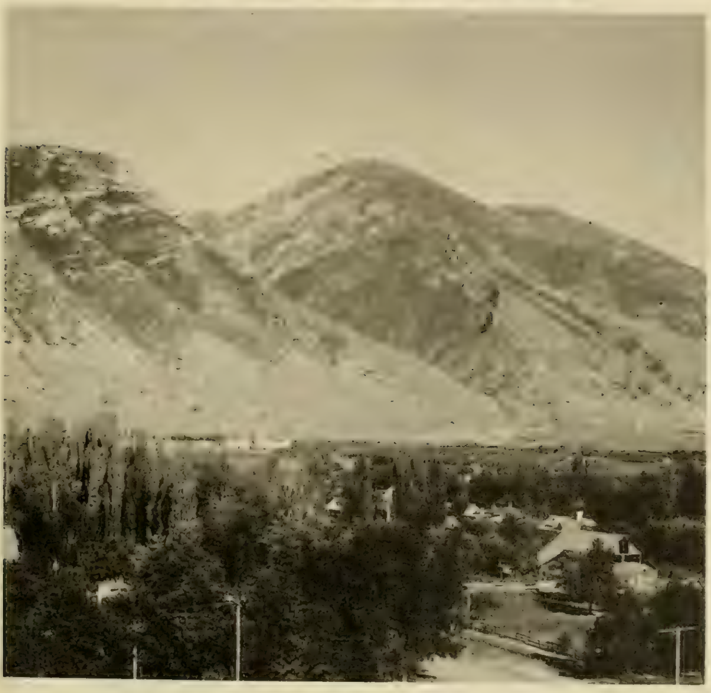
A. EASTERN FACE OF THE PUEBLO MOUNTAINS.



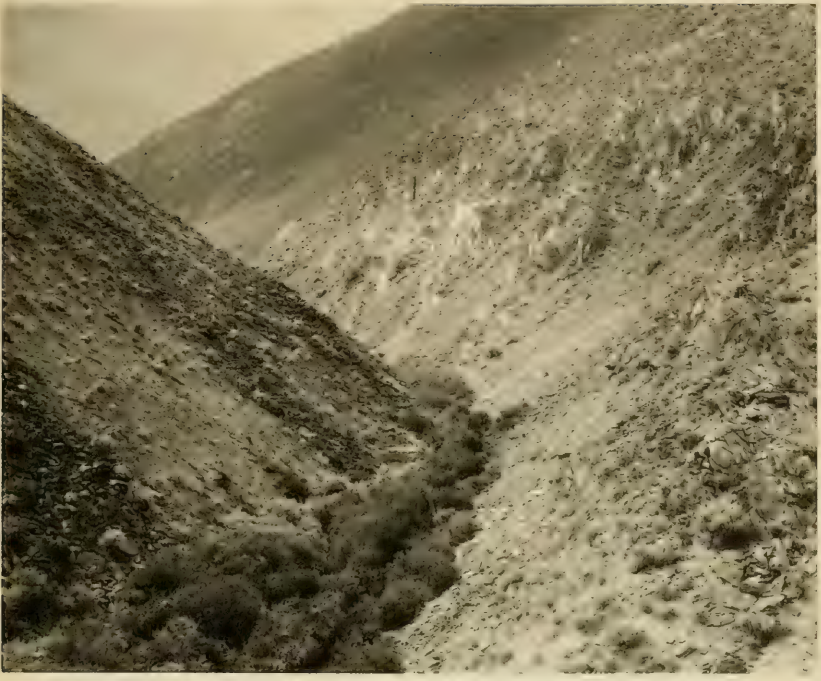
B. SOUTHERN END OF THE PUEBLO MOUNTAINS.



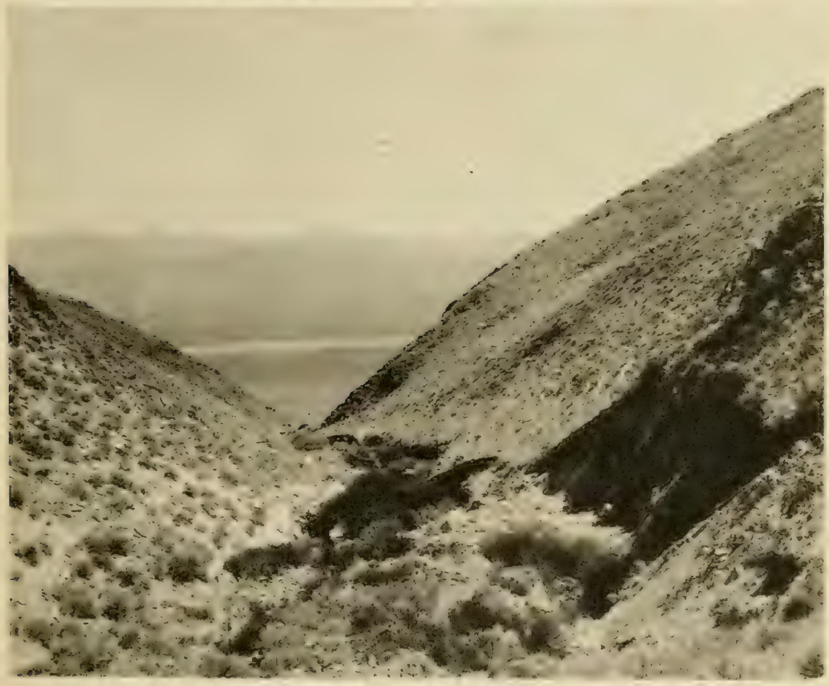
A. ROCK CANYON IN THE PROVO WAHSATCH.



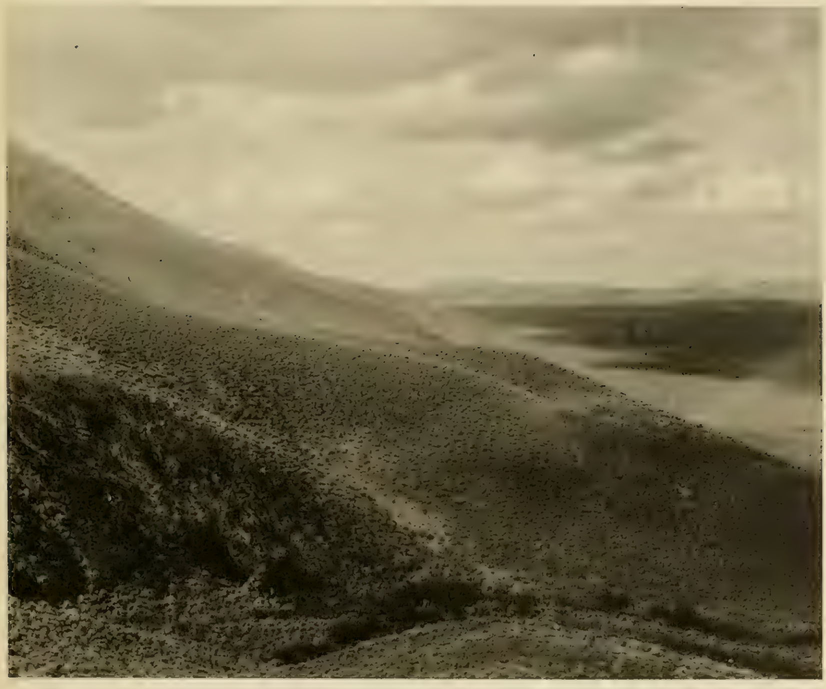
B. SLATE CANYON IN THE PROVO WAHSATCH.



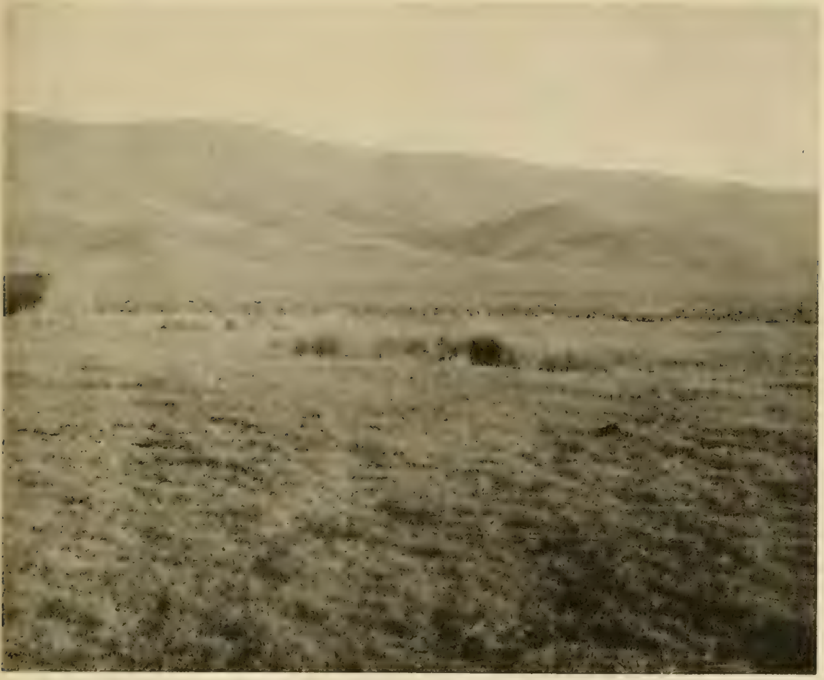
A. CANYON IN THE PUEBLO RANGE, NEAR DENIO.



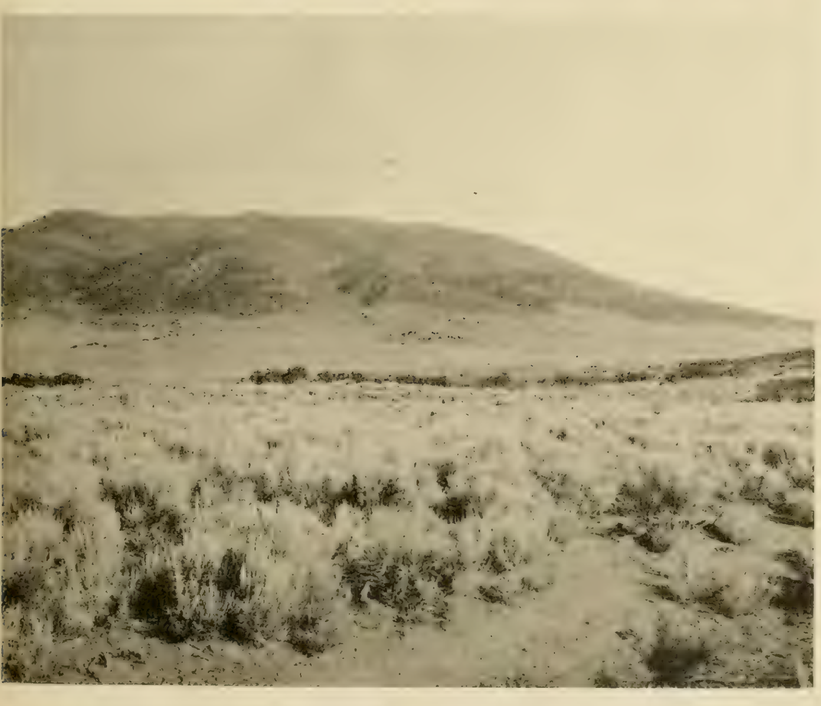
B. CANYON IN THE PUEBLO RANGE, NEAR DEEGAN'S.



BROKEN FAN IN THE PUEBLO RANGE.



A. STEIN MOUNTAINS, NEAR ANDREWS.



B. A RESIDUAL MOUNTAIN RANGE IN SOUTHWESTERN UTAH.

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GEOLOGICAL SERIES, Vol. VI. No. 4.

POSTGLACIAL AND INTERGLACIAL (?) CHANGES OF LEVEL AT CAPE ANN, MASSACHUSETTS.

By R. S. Tarr.

WITH A NOTE ON THE ELEVATED BEACHES.

By J. B. Woodworth.

With Thirteen Plates.

CAMBRIDGE, MASS., U. S. A.:
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No. 4. — *Postglacial and Interglacial (?) Changes of Level at Cape Ann, Massachusetts.* By R. S. Tarr. *With a Note on the Elevated Beaches.* By J. B. Woodworth.

Nature of the Work. — Investigation upon the recent geology of Cape Ann was begun by me in 1887 in connection with work for the United States Geological Survey under the direction of Professor Shaler. The results obtained during that period have been published in the Ninth Annual Report of the United States Geological Survey (pp. 529–611). Since that time frequent visits to the region have furnished opportunity for further study, attention being specially directed to tracing the evidence of recent elevation along that coast. The discovery of well-defined beaches and other evidences of uplift, first made in 1887, received very distinct support from these later studies, and it is a statement of these additions to the evidence proposed by Professor Shaler that constitutes excuse for this paper.

In the prosecution of the work very material aid has been given by Mr. John L. Gardner, whose interest in the investigation led him to generously undertake the expense of a careful, detailed survey of some of the most pronounced beaches; and the maps which were made for this purpose by Prof. A. E. Burton of the Massachusetts Institute of Technology are used as illustrations in this paper (Plates **2**, **3**, and **4**). The preparation of these maps is a matter of distinct importance, since they place on record the form and elevation of these beaches, which are in danger of speedy destruction because of the encroachment of summer residences upon their sites.

Stripped Areas and Stratified Deposits. — The evidences that the sea has covered the coastal margin of Cape Ann at least up to an elevation of 40 to 60 feet above the present level are very distinct and of several kinds.

In the first place, as clearly stated by Professor Shaler, while the center of Cape Ann is heavily strewn with morainal deposits, the coastal strip is almost clear of such accumulations and is marked by a distinct predominance of bare rock. Above an elevation of from 50 to 60 feet the soil is almost entirely morainic till, more sandy than is common in many regions, but nevertheless distinctly unstratified. Below this elevation, on the other hand, in nearly every case where I have seen a cut in the soil, it is made of stratified materials, sometimes only very roughly assorted, but in many places perfectly stratified.

At the elevation of from 40 to 90 feet there are frequent bare ledges of rock causing some of the unique bits of scenery which have rendered the Cape famous among summer visitors (Plate **5**). Below this strip of bare rock are level stretches of stratified material. When the studies were first begun in 1887, the suggestion at once arose that this stretch of bed rock, which so closely resembles the stripped area of granite just above the present high-tide mark, in reality represents a stripped area produced at a time when the waves were working at a higher level and were able to wash the loose soil from the ledges, as they have so effectually done all along the exposed coast of the Cape at the present level.

The resemblance between the upland topography at an elevation of from 40 to 90 feet and the present coast line is in many places clearly defined in the way just described; but, just as along the present coast there are many differences from place to place, in accordance with the location with reference to exposure to waves, or with reference to the nature of the under rock, so at the upper levels there are also variations from place to place. For instance, along the Pigeon Cove coast, one of the most exposed parts of the Cape, the jointing of the granite is of such kind as to furnish sloping layers of rock dipping seaward, much as would be the case if there were a series of sedimentary beds with a seaward dip. The waves along the present coast wash up over the sloping granite for a long distance, and, except in one or two places, the coast is not bordered by beach accumulation. At first the failure to discover evidence of former depression in this part of the coast was considered very puzzling; but as the studies were carried on in more detail, it soon became evident that beaches would probably not have been formed here. Instead, as along the present coast, the granite was completely stripped of all soil, though it is now covered in places with a thin veneer of gravel resulting from the postglacial decay of the bed rock.

On Eastern Point, which forms the eastern boundary of Gloucester Harbor, the bare rock area is much greater than in any other section of the Cape of equal size. Here even the higher hills are washed clear of drift; and in this part of the Cape the raised beaches are very well developed. This is in harmony with what one would expect, for since the ice movement was from the northwest, the southeastern margin of the Cape was first exposed to the waves; and even while the moraine of Cape Ann was being built by an ice stand, Eastern Point, and the eastern part of the Cape in general, which were then at a lower level, were open to sea action.

Whether the land at that time stood even lower than the limit indicated by the beaches cannot be positively stated, although the very rocky and bouldery condition of the eastern section of the Cape, including the bear-den moraines, suggests this explanation. An alternate explanation of the rocky eastern section is that while the ice was standing here, the waters formed by its melting, and from the melting of the snows in the spring, were enabled to wash the loose accumulations from the hills of Eastern Point and elsewhere. That is the explanation of similar conditions in Greenland; and, in fact, there is a close resemblance, in a small way, between the bare rock hills of Eastern Point, with the frequent perched boulders, and the rocky surface of the Greenland coast line, which is strewn with boulders perched often in rather unstable positions.

Sand Dunes. — On the island which forms the end of the Cape there are at the present time practically no sand dunes, with the exception of some low ridges just above high tide, developed along two or three of the beaches, especially those on the southeastern side. West of the estuary of Squam "River," however, there is an extensive development of sand dunes supplied from the sand of Coffins' Beach. These dunes had their beginning a little over a century ago, when the forest was stripped away, and are still in process of formation. On the opposite, or eastern side of Squam "River" is a stretch of dunes (Plate 1) extending with considerable continuity from the village of Annisquam to Folly Cove beyond Lanesville, a distance of three and a half miles; but these dunes have long since ceased forming, and there is no evidence of source of supply for them. Instead of being composed of white sand, and supporting only the sparse sand dune vegetation, these dunes (Plate 6) are throughout, from top to bottom, discolored to a yellow through the formation of hydrous oxides of iron formed by the decay of the mica and hornblende bits which constitute a part of the dune sand. These dunes reach to an elevation of from 80 to 100 feet above sea level, and some of the individual hills have a height of fully 25 feet. In all but one of the places where the bottom could be seen, the sand rests upon bed rock with no soil between. The exception mentioned is near the head of Lobster Cove at Annisquam, where the sand rests upon an angular, roughly stratified accumulation of pebbles, clay, and sand resembling the deposits now being made along the coast of this well-enclosed cove. In several places, scattered, well-rounded pebbles were found resting on the granite at the base of the sand.

There can be no question that the sand dunes of this locality have been formed in the past when conditions were very different from those of the present; for now the entire coast line in this region is granite rock without the vestige of a beach to supply the sand. Nor is there any interior supply; it seems to have come from the seaward side. It might, of course, be assumed that when the waves began their work after the ice retreated, they stripped the soil from the rock and formed beaches which have since been destroyed, leaving no evidence of their existence, and that all this happened while the land was at its present elevation.

This explanation seems inadequate for at least two reasons. In the first place, the presence of the rounded pebbles suggests the presence of the sea at higher level; and, in the second place, the present outline of the coast is not of such a form as to lead to the development of beaches. It is altogether too straight a stretch of granite; but if the land were depressed the coast line would become very much more irregular, and sand beaches might well develop in the bays. With the disappearance of the waves from the land through elevation, the beach sands might well have been blown about, forming sand dunes.

While by itself this area of sand dunes, although strongly suggestive, could not be deemed conclusive evidence of former depression of the land, when taken in connection with the other evidences of depression it constitutes a link in the chain of evidence of such importance that it must be considered.

Delta Deposits. — Since there are no large streams on Cape Ann, well-developed deltas would not be expected. Only one perfectly defined delta was found on the Cape. It is located near the road from Gloucester to Rockport, and is best seen where a branch road extends from the one just mentioned down to Good Harbor Beach (F, Plate 1). At this point the delta is bisected by a small stream flowing from the direction of Cape Pond. The crest of the delta is about 50 feet above sea level, and it has a length of about one-half mile, with a width of a quarter of a mile. Along the road to Good Harbor Beach a cut reveals the internal structure of the delta to the depth of 25 feet, showing distinctly cross-bedded sands and gravels dipping seaward and overlain by horizontal surface beds of gravel. The crest is remarkably level, though with a gentle seaward slope; and upon its surface, in several places, are linear indentations, evidently channel ways. It faces away from the ice, and toward the open sea, and therefore there is no reason for considering it a sandplain in an enclosed valley dammed by the ice.

A deposit apparently of the same origin occurs near the mouth of the Alewife brook (K, Plate 1), the outlet of Cape Pond. It is now so badly destroyed by excavations for street grading that the form is not preserved; but before these excavations were made the features of the delta were plainly seen. One feature in connection with this deposit is the presence of abundant boulders of large size, showing that while the water was depositing the layers there was some means — as floating ice — for the transportation of large rock masses. The Alewife brook delta deposit extends up stream for a long distance, the valley being bordered, sometimes on both sides, but more often on only one, by stratified, terrace-like beds. One of these is locally known as the "Sand Pit," and even farther upstream than this, at about the level of the former coast line, is an extensive stretch of level land now for the most part occupied by a swamp. The association of these features with the largest brook on the Cape leads to the belief, when taken in connection with the other evidence, that this is really a delta formed in the sea during a lower stand of the land.

At that part of the delta first described, the Alewife brook turns abruptly at right angles to the north and changes its character from a brook to a tidal stream called Mill "River." A large part of Mill "River" valley bottom is salt marsh; but this is flanked on either side by stratified beds which extend from Riverdale into the city of Gloucester (I J, Plate 1). So much building has been done over a large part of this level, stratified area that one cannot now tell what its original condition was; but in that region, wherever cuts have been made at levels below the 45 foot contour line, they have revealed stratified drift. This region is so enclosed by hills that it is impossible to consider these deposits as beaches, but their uniformity of extent at the former sea level leads to the belief that they are connected in origin with the former sea level. There is now no stream which could have formed such extensive beds of stratified deposit, but it is noteworthy that they are located along the broad north-south depression which, at the present stand of the sea, completely cuts the end of Cape Ann from the mainland, transforming it to an island. While the ice front was building the Cape Ann moraine, water from the melting glacier was doubtless supplied to this valley; and it is also possible that it served as the outlet for a subglacial stream, which would account for the stratified deposits that abound along the valley sides and bottom.

This explanation, which seems the only possible one, would assign to the stratified beds in the neighborhood of the city of Gloucester an origin similar to that of some sandplains, although the development of surface features is not nearly so typical here as in some of the sandplains near Boston.

If a depression of Cape Ann can be proved to have occurred in post-glacial times to the amount of 40 feet or more, it would be expected that similar proof could be found in other regions near by. I have made no attempt to extend the study beyond Cape Ann, but the suggestion has occurred to me that at least some of the sandplains of eastern Massachusetts, and some of the broadly extended stratified beds near the mouths of large streams, are really delta deposits made when the land stood lower than at present.

Beaches. — In a number of places along the shore, especially the eastern and most exposed shore of the Cape, distinct beaches were found at the elevation indicated by the other stratified deposits described above. It does not seem worth the while to take the space for specific description of many of these beaches, and therefore only three or four of the best will be described.

A very interesting bar, evidently resulting from wave wash, is found near the southern end of Eastern Point on the site of the old government fort (A, Plate **1**). The bar is crescentic in shape and is isolated from higher land. Its crest has an elevation of 50 feet. By itself it would prove nothing, but its elevation, which is the same as that of much better developed beaches near by, indicates that it is of wave origin. The appearance of the area near this bar indicates that there was here either a shoal or else a low island which the waves gradually washed away, leaving a bar on one end. Its position and form are indicated on the map.

Less than a mile to the northeastward from this is a well-developed cusp whose position is marked on the map (B, Plate **1**). It is so well defined that the United States Coast Survey topographers gave to it a special contour, as will be seen on the United States Geological Survey map, which in this place is based upon the Coast Survey map. This beach is one that Professor Burton surveyed for Mr. Gardner to be used in this paper, and the maps made from this survey are reproduced as Plates **2** and **3**. By the maps it will be seen that along the present coast line there is a rocky stretch of coast toward the northeast, succeeded toward the west by a pebble beach which grades into a sand beach on the extreme west. The modern beach reaches an elevation of a little over 14 feet above mean sea level, and behind this is a swamp 5 feet lower. It stands, therefore, as a bar, and its outline is that of a cusp. Almost parallel to the present beach, and from 500 to 700 feet inland, is another bar reaching an elevation of 41 feet and sloping away from the crest in both directions. It is flanked by a swamp about 15 feet lower than the crest. Its form is distinctly that of a beach, and cuts that have been made in it prove it to be composed of well-stratified materials. The surface is strewn with large water-worn pebbles resembling those of the modern beach. Back toward the northwest, the bar broadens until it reaches the base of some low rocky hills (Plate **5**) which have the appearance of having been stripped of their drift cover. The base of this series of rocky hills is from 42 to 47 feet above mean tide level.

If the land could now sink far enough to permit the waves to wash the base of these rocky hills, all the land at present to the seaward of them would be below the water, although some places, especially at the eastern end of the bar, would reach almost to the high-water mark. Assuming that nothing had been stripped from any of the hills, the condition would then be a coast line at the western margin of the bar and a series of shallows at the eastern margin. The prevailing direction of effective waves approaching such a coast then, as now, would be from the northeast. Breaking upon the shoals of the eastern end they would remove whatever loose fragments were available, and drive them toward the southwest. The loose fragments derived from the western margin would be driven onward toward the south and, as the waves advanced into this more or less completely enclosed arm of the sea, one would expect them to build a crescent-shaped beach similar to the crescent beaches which are so common along the coast. Indeed, the beach at the present sea level (described above) is such a crescent bar forming a barrier which has cut off Niles Pond from the sea.

Another elevated beach, in some respects resembling the one just described, is found west of High Pebble Beach (D, Plate **1**). It faces the northeast, and skirts a line of rocky hills on the north and south sides, while on the west side it stretches across as a bar (Plate **7**) from the hills on one side to those on the other. Its form is well shown on the accompanying map, also made for Mr. Gardner by Professor Burton (Plate **4**, B). The crest of this bar is 52 feet above the present tide level. The fact that it is higher than the bar just described is doubtless due to its exposure. In the case of the beach first described (Plates **2** and **3**), the waves from the northeast must have been greatly interfered with by shallows, and possibly at first by low islands; but the beach back of High Pebble Beach was exposed to the full force of the northeast waves. Its form is well shown not only on the map (Plate **4**), but also in the photograph (Plate **7**). Like the other beaches, this one is composed of well-assorted stratified materials with many distinctly rounded pebbles. A photograph of a cut in this beach is reproduced as Plate **8**.

About three-quarters of a mile north of this beach, and back of the Moorlands Hotel is further evidence of the depression of the land. There is a rock cave flanked at the base by a number of disrupted boulders, the whole region being closely like the present condition at Bass Rocks, where the sea is at present beating and rending similar masses of rock from the ledges.

A half mile north of this, along the electric car line from Gloucester to Good Harbor Beach, at the base of the hill which lies to the south of the road, is an accumulation of stratified material (E, Plate **1**). While not exactly like a beach, similar to those at present existing on the coast, it does resemble what one would expect to be formed by rapid wave work, in a protected bay along a drift-covered coast.

There are numerous other stratified deposits along this level and below it. One of the best elevated beaches along the coast occurs just west of Whale Cove, near Turk's Head Inn (G, Plate **1**). This is fully described in the accompanying paper by Professor Woodworth.

Absence of Fossils. — One of the reasons for not having previously published the evidence of former depression of the land in Cape Ann has been the hope, long deferred, that fossils might be found in some of the deposits. I have searched with care in every cut that I have seen on Cape Ann in the last sixteen years, and have never found a single fossil in the deposits of postglacial age. With the abundance of such fossils in the beaches further north, as in Baffin Land, this absence of organic remains seems difficult to explain, and for a long time led me to question whether some other explanation of the phenomena at Cape Ann could not be suggested; but the evidence of depression seems so perfect that, notwithstanding the absence of fossils, I feel convinced; and I am obliged to assume that their absence is to be accounted for by adverse conditions, such as the short stand of the land and the coldness and muddiness of the water. It must be confessed that when one finds an abundance of animal life at the very base of the Greenland glacier, in such a position as to be thrown to the surface when icebergs break away from the glacier, this explanation seems weak. However, the deposits on Cape Ann were made at the edge of a rapidly retreating ice front, and marine life may not have advanced this far while the land was lower.

It is, of course, possible that fossils exist here, but have not yet been detected. I have been told of the former discovery of fossils in a number of places, but evidence of this kind is of little value; and each time that I have looked where they were once found, it has been discovered that they no longer occurred there.

Summary. — While a single one of the evidences set forth in this paper might not be considered proof of depression of Cape Ann in post-glacial times, the accumulation of evidence from several directions is such as to make the conclusion necessary that this part of the coast has been depressed to a level at least 40 to 60 feet lower than the present.

Summarizing this evidence, it may be said to consist first and most prominently of a number of well-defined beaches at a level of from 35 to 60 feet. At about the same elevation, over most of the Cape, stratified drift is found wherever cuts are made, and some of this is evidently delta deposit. While much of the stratified material cannot be positively associated with wave action, or with the action of streams at present existing, its occurrence below a certain level, while above that level there is much unstratified drift, and almost no stratified material, is suggestive. That these deposits do not more frequently assume the forms of the present coastal deposits is readily understood when we consider the brief duration of the lower stand of the land in comparison with the present long stand.

The extinct sand dunes of the Lanesville region, occurring where there is now no apparent supply of sand, and long since having ceased forming, is also suggestive of a lower stand of the land, especially since well-rounded pebbles are found beneath this sand in some places.

Interglacial (?) Beds. — In 1866 Professor Shaler announced[1] the discovery of fossils from a deposit of stratified drift on Cape Ann not far from the Pavilion beach. His list of fossils is as follows: —

> "LEDA. Two specimens.
> MODIOLA DISCREPANS Say. Several specimens.
> MYA TRUNCATA Linn. ?. Several specimens.
> MESODESMA ARCTATA ?. Very doubtful.
> NUCULA SAPOTILLA?.
> PANOPEA ARCTICA Gould?.
> SAXICAVA DISTORTA Say.
> Five or six specimens of Lamellibranchiata not identified.
> Crustacean remains, plentiful but very fragmentary."

While engaged on the work at Cape Ann with Professor Shaler, both he and I tried to rediscover this locality, but without success. In 1897, however, while extensive excavations were being made at Stage Fort (L, Plate 1) on the western end of Pavilion Beach I found these beds revealed in such remarkably perfect condition as to show not only the fossil contents, but many other facts as well. Some of the features revealed there are very well illustrated in the figures (Plates 9-13). It will be noticed that there are two sets of beds, one very much contorted and stratified, the other overlying these unconformably. The latter deposit is nothing more than the ordinary till of the region, being somewhat sandy and very bouldery, as is all of that upon Cape Ann. It rests upon the grooved and eroded under-beds with a very distinct unconformity.

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[1] Proceedings Boston Soc. Nat. Hist., 1866, Vol. II., pp. 27–30.

The strata below are folded in such a way as to be even contorted in places, and there is thrust-faulting. These beds are for the most part clays and sandy clays entirely unconsolidated, although some layers are very compact. One or two of the layers are pebbly, especially a layer at the base, which is shown in Plate 12. Scattered through the contorted layers are numerous angular boulders, some of them shown in the pictures. In some cases these reach a weight of one to two tons. Some of them are foreign to the region, like the erratics which occur on various parts of the Cape.

The stratification proves sedimentation in water, and the scattered boulders prove a transporting power different from that which brought and deposited the layers of sand and clay. They must have been carried by floating ice, having previously been brought from a distance. The suggestion occurs at once that these were brought during the first advance of the glacier and deposited in the sea at a time when this part of the land was below sea level. The ice of the second advance of the glacier overrode these interglacial (?) deposits and failed to remove them all, doubtless disturbing their position and causing the intense contortion noticed, and at the same time placing upon the surface the veneer of till.

Deposit below sea level is also proved by the presence of the fossils mentioned by Professor Shaler and those that I collected. The coldness of the water is also proved by these, suggesting the possibility of floating ice in the neighborhood. While considerable numbers of fossils were obtained from the fossil-bearing beds of the series, their imperfect state of preservation rendered transportation so difficult that, when I came to unpack them, I found most of them crumbled to bits; and upon the next visit the abundant fossil-bearing layer was no longer exposed; but among those which were sufficiently well preserved for identification two, also found by Professor Shaler, were characteristic of cold water. One, *Yoldia siliqua*, is also found fossil in the clays near Portland and Montreal, and occurs in the present waters of the Arctic, as at Beechey's Island and Greenland. The other, *Aphrodite groenlandica*, is a distinctly northern form.[1]

The fossil-bearing layer is from 15 to 20 feet above mean sea level, and the interglacial (?) beds extend fully 10 feet higher, indicating subsidence during this interglacial (?) time fully 30 feet below the present level. How much has been removed by erosion from the top of these beds can not be stated, but it is evident that not a little has been carried off. The clayey layers also suggest a subsidence sufficient to remove the area from the immediate neighborhood of the rocky coast; and the presence of boulders, some of which are fully two tons in weight, suggest sufficient depth for large masses of ice to float. It seems difficult to account for these transported fragments in water having a depth less than a hundred feet.

Other deposits of the same kind may be expected in different parts of the Cape, and at levels considerably above this; but it is hardly probable that such extensive deposits will be found elsewhere, for those at Stage Fort have a peculiarly favorable situation for preservation, being situated on the lee side of a high range of hills which has protected them from removal. It is unfortunate that neither the wave action nor the excavations that were made reveal the base of these beds; and, therefore, it is not possible to state with certainty that these are interglacial rather than immediately preglacial beds, although there is, in fact, little reason to doubt their interglacial age.

Note on the Elevated Beaches of Cape Ann, Mass.

By J. B. Woodworth.

A few years ago, under Professor Tarr's guidance, I saw the elevated beaches which are described in his paper as lying on the seaward face of Eastern Point, Cape Ann. The notes which are here appended to his paper are therefore a direct outgrowth of his own work on these elevated beaches. The discussion concerning the extension of the marine limit southward is, however, made independently.

In the fall of 1902, in the company of Mr. J. W. Goldthwait of the Geological Department of Harvard University, I made a visit to Rockport and sought for shore lines from the crest of Pigeon Hill at the cove of that name, down to the existing sea level, and thence southward along the coast between Gap Head and Emerson Point. The results obtained, since they confirm and somewhat extend Professor Tarr's observation in the same field in regard to the elevation of the beaches are here given, without, however, the precise elevations which it is hoped later to obtain, by levelling, upon the marine limit at Rockport.

---

[1] I am indebted to Prof. G. D. Harris of Cornell University for the identification of these fossils.

Pigeon Hill is a drumlin rising from an almost driftless area of granitic rocks. The hill was selected as a point of beginning the search for the marine limit, for the reason that if this hill failed to show beaches it seemed fair to conclude that the upper marine limit did not rise above the 100 foot contour-line which encircles the hill. The eastern and northern base of this drumlin is outlined by the 80 foot contour line, its western and southern base approximately by the 100 foot contour line. The northern and eastern slopes of this hill, which would have been exposed to heavy waves from the sea, show no scarps or lines of water action above the 100 foot line. On the southwest slope of the hill, there is a marked terrace between 140 and 145 feet, outer and inner edges respectively, by aneroid measurements. This terrace, however, lacks horizontality; it rises either way toward the middle of the side of the hill. From its inner edge rises a healed scarp which, together with the terrace, indicates an alteration of the original lenticular contour of the drumlin. The non-horizontality of the terrace, and the failure of built margins in the form of gravel or sand bars, relegates the terrace to the group of little understood forms dependent on either glacial erosion or glacial stream action taking place during the disappearance of the ice-sheet from the vicinity. It certainly does not appear to the writer that the criteria of wave action are exhibited in this case.

All along the shore, at least from 80 to 90 feet downward, there occur, bordering and between rock cliffs, sloping deposits of sand overlaid by coarse rubble, the ensemble of which is not that of glacial drift, but rather that of deposits making along a rocky coast beneath the water level. These deposits were noted and similarly interpreted by Shaler and Tarr in the report on the geology of Cape Ann published some years ago.[1]

Elevated Beach and Bar at Whale Cove. — The most perfectly formed and highest beach I have seen on Cape Ann is that noted by Professor Tarr, as lying immediately back of Whale Cove, between the shore and the public road. Traversing this portion of the coast from north to south, one comes, on approaching the vicinity of Whale Cove, to a gently shelving flat south of a region of bare rock knobs. This flat ends on its inner margin against a boulder wall of a weak morainal appearance. The flat is strewn with numerous boulders, but where the sod is turned up water-worn stones appear. The upper inner limit of the beach flat according to the contoured map is about 80 feet above the present sea level, but aneroid readings, made at the time of my first visit and later, indicate a lower level of about 65 feet.

---

[1] N. S. Shaler: The Geology of Cape Ann. 9th Report of the Director of the U. S. Geological Survey, 1889, p. 573.

South of this place, and retreating inland somewhat from the boulder line just described, is a well-formed bar with level top thrown southward across a slight depression extending landward between bare rocky knobs west of the road. The bar at its southern end is trenched by a small wet-weather brooklet draining the back-bay area behind the bar. The materials of the bar, as shown in a small pit, are rudely assorted water-worn cobbles, gravel, and sand closely resembling glacial stream detritus.

This bar is slightly concave toward Whale Cove. From its crest the ancient beach slopes away in a graceful, saucer-shaped surface at an angle of about 4 degrees to a low bluff of underwater sands 32 feet high bordering Whale Cove.

The bar is composed of water-worn gravel with occasionally larger stones. A section in it is exposed at the breach above mentioned. The elevation of the crest, so far as can be judged from the contours of the map, is about 90 feet, but the bar itself is not clearly indicated on the map with 20 feet contour intervals. Aneroid readings by myself and Locke, hand-level determinations by Mr. Laurence La Forge, U. S. G. S., gave 78 and 77 feet respectively above mean tide level.

A few boulders occasion the outer slope from the crest of the bar down to the bluff on the shore of Whale Cove, and much water-worn gravel appears everywhere at the surface in the upper part of the slope. Lower down over the underwater sands a rubbly layer occurs which is well exposed at the summit-line of the bluff. The finely stratified sands in this bluff have as yet afforded no fossils.

Farther south weak gravel bars, stretching amid rock knobs, occur about the 90 foot line in the manner described by Professor Tarr near Turk's Head Inn. Back of Emerson Point on the southern slope of the southward projecting ridge next the shore, two small spits of gravel occur between 60 and 80 feet, according to the contours of the map. These occurrences, as well as the bar at Whale Cove, indicate the southward drift of the shore material.

The evidence of strong wave action as high as 80 feet above the present sea level on this part of the coast of Cape Ann, considered in connection with the occurrences of an elevated sea-floor already described by Stone and others on the coast of Maine where marine fossils have been found above the latest glacial drift, makes it difficult, it seems to me, to escape the conclusion that marine action rather than glacial lake waters was also concerned at Cape Ann in the making of the beaches described by Professor Tarr and myself. In a paper now in preparation, I purpose to show that in the southern part of Massachusetts the last ice-sheet existed longer, along and off the coast, than it did on the mainland west of Cape Cod bay, thus allowing the formation and temporary existence of what may be termed proglacial lakes, or bodies of fresh-water, held in front of the ice by a glacier-dam crossing the mouths of valleys, already freed from ice; such a body of water as Professor Crosby has claimed, may have existed in Boston harbor, and even northward along the coast. The fetch of the waves from the northeast necessary to produce the long shore drift observed at Whale Cove on Cape Ann, however, is quite beyond the possibilities of any contemporaneous glacial lake which the facts discovered in the Cape Cod district would warrant.

EXPLANATION OF PLATES.

PLATE 1.

Map of Cape Ann. A, bar on the site of old government fort; B, bar mapped in Plates **2** and **3**; C, planed-off island with rim of beach; D, Beach represented in Plates **7** and **8**; E, stratified drift indicating wave action; F, Delta; G, Whale Cove deposits; H, dunes; I, J, K, stratified deposits in Mill River valley; L, Stage Fort, till-covered fossiliferous (interglacial (?)) beds.

PLATE 2.

Contour map of elevated (40 foot) V-shaped bar at Eastern Point, B, Plate **1**.

PLATE 3.

Contour map of the beach (B) represented on Plate **2**.

PLATE 4.

Beach (B) at Eastern Point (Plate **1**, D), connecting bare rock hills R, R.

PLATE 5.

Bare rock ledge (wave stripped?) at Eastern Point, looking from the beach, Plates **2** and **3**. Photograph by J. L. Gardner.

PLATE 6.

Open oak forest on the extinct sand dune area of Lanesville. (Locality H on Plate **1**.)

PLATE 7.

Crest of the beach, BB, Plate **4**. The low rock hills showing on the extreme left, and the swamp in front appearing in the foreground. View from locality V, Plate **4**. Photograph by J. L. Gardner.

PLATE 8.

Cut in the beach at locality C, Plate **4**. Photograph by J. L. Gardner.

PLATE 9.

The interglacial (?) beds at Stage Fort, Gloucester, showing the crumpled strata. Photograph by J. L. Gardner.

PLATE 10.

Unconformity between the till and the crumpled interglacial (?) beds. Photograph by J. L. Gardner.

PLATE 11.

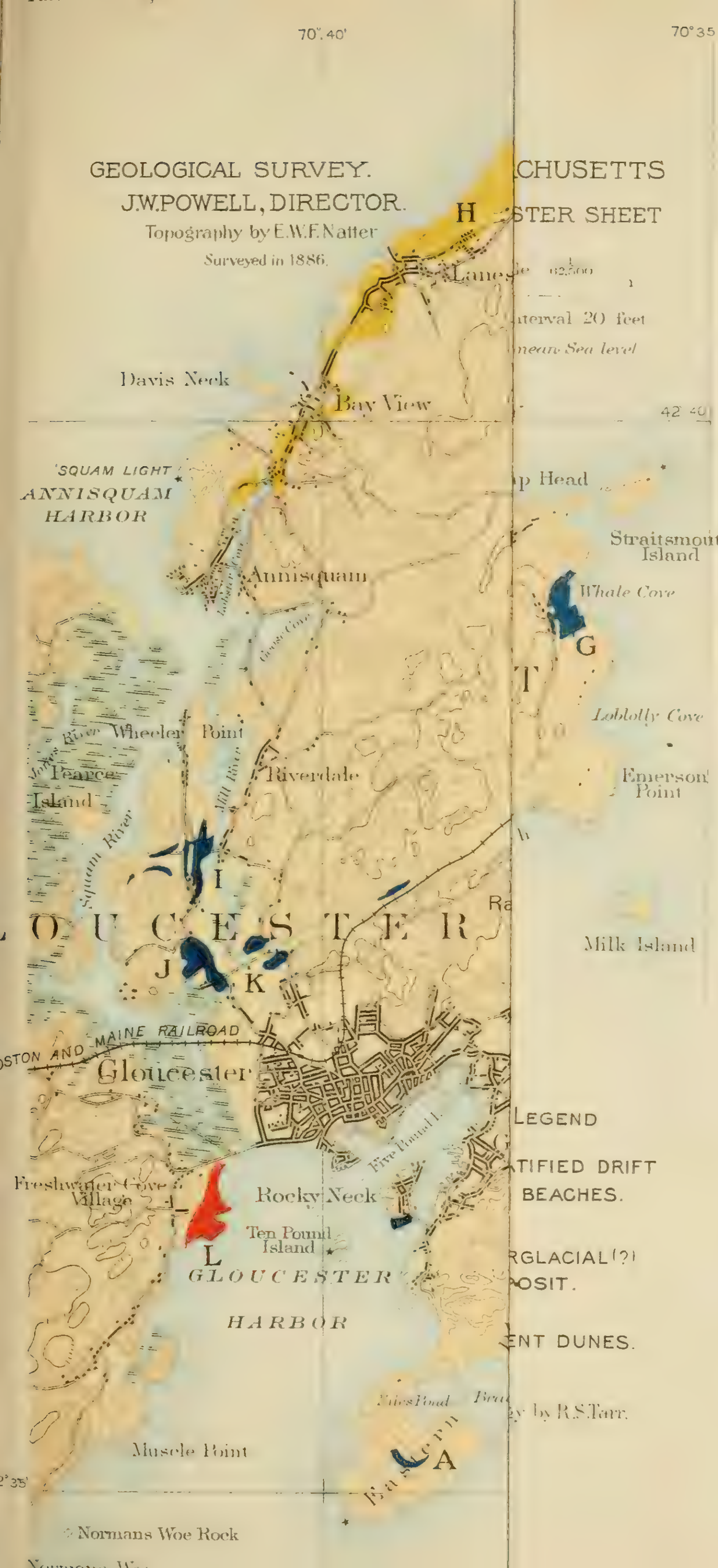
Crumpling and thrust-faulting in the interglacial (?) beds at Stage Fort. Photograph by J. L. Gardner.

PLATE 12.

Gravel layer (at left of cut) beneath the interglacial (?) clays; till above. Photograph by J. L. Gardner.

PLATE 13.

Large boulders in the interglacial (?) beds. The till has been removed from the top. Photograph by J. L. Gardner.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J.W.POWELL, DIRECTOR.
Topography by E.W.F.Natter
Surveyed in 1886.
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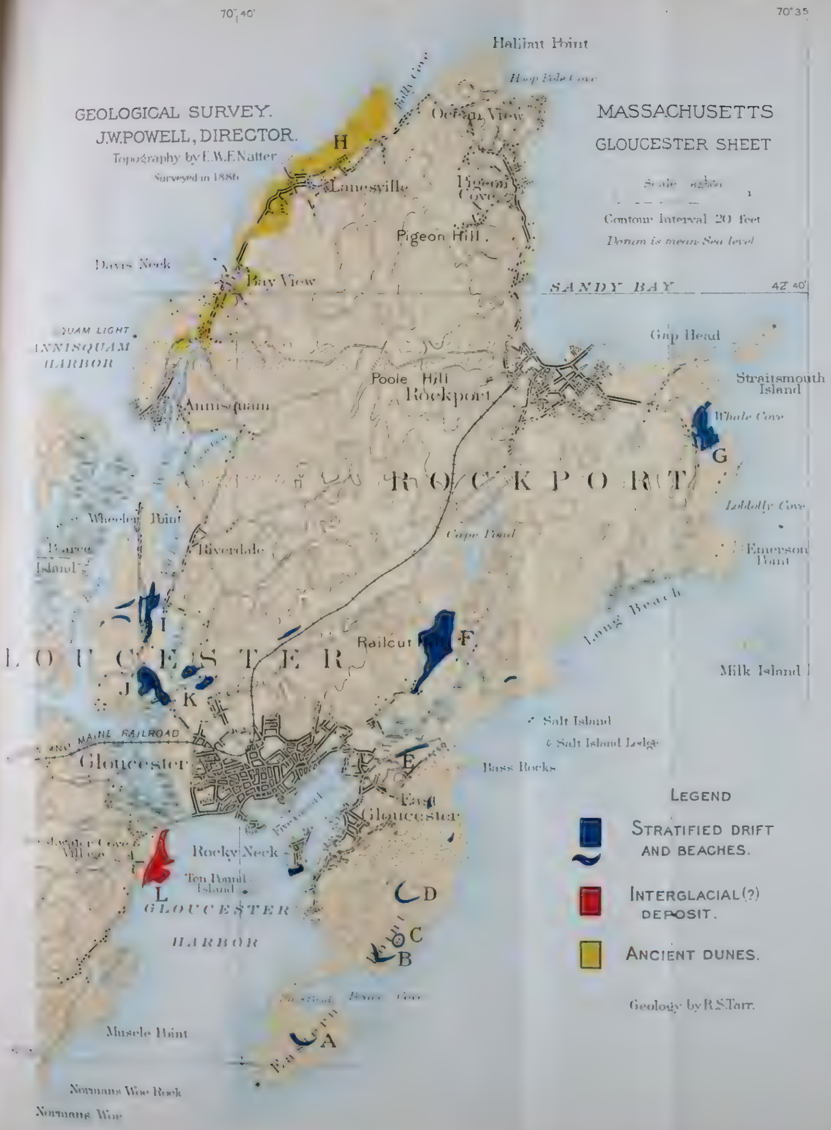
Normans Woe

Plate 1.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GEOLOGICAL SURVEY.
J.W.POWELL, DIRECTOR.
Topography by E.W.F.Natter
Surveyed in 1886
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GLOUCESTER SHEET
Scale 1/62500
Contour Interval 20 feet
Datum is mean Sea level
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Hoop Pole Cove
Folly Cove
Ocean View
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Pigeon Cove
Pigeon Hill
Davis Neck
Bay View
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Gap Head
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Whale Cove
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ANNISQUAM HARBOR
Annisquam
Poole Hill
Rockport
ROCKPORT
Loblolly Cove
Emerson Point
Cape Pond
Wheeler Point
Pearce Island
Riverdale
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Long Beach
Railcut Hill
F
GLOUCESTER
Milk Island
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Salt Island
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Gloucester
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Bass Rocks
East Gloucester
Rocky Neck
Ten Pound Island
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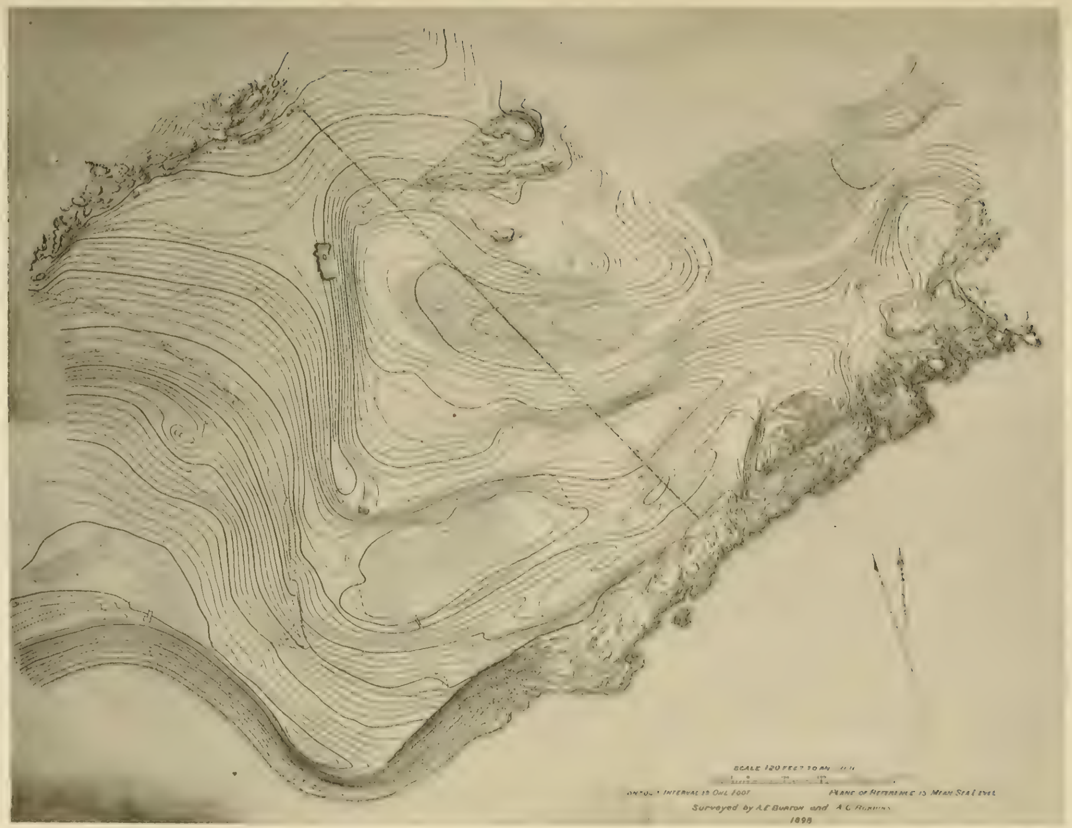
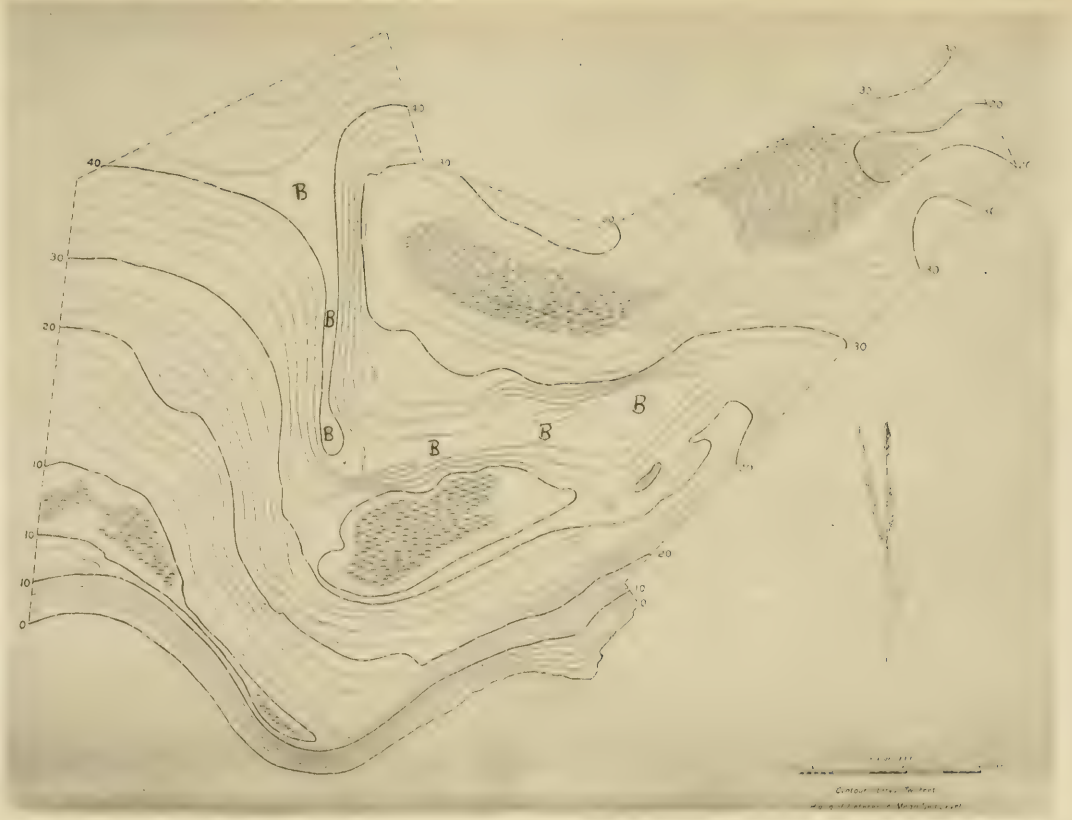
Eastern Point
Brace Cove
Muscle Point
Normans Woe Rock
Normans Woe
LEGEND
STRATIFIED DRIFT AND BEACHES.
INTERGLACIAL (?) DEPOSIT.
ANCIENT DUNES.
Geology by R.S.Tarr.


SCALE 120 FEET TO AN INCH
CONTOUR INTERVAL IS ONE FOOT
PLANE OF REFERENCE IS MEAN SEA LEVEL
Surveyed by A.E. Burton and A.C. Robbins
1898

HELIOTYPE CO., BOSTON.

CONTOUR MAP OF ELEVATED (40 FOOT) V-SHAPED BAR AT EASTERN POINT. (B, PL. 1).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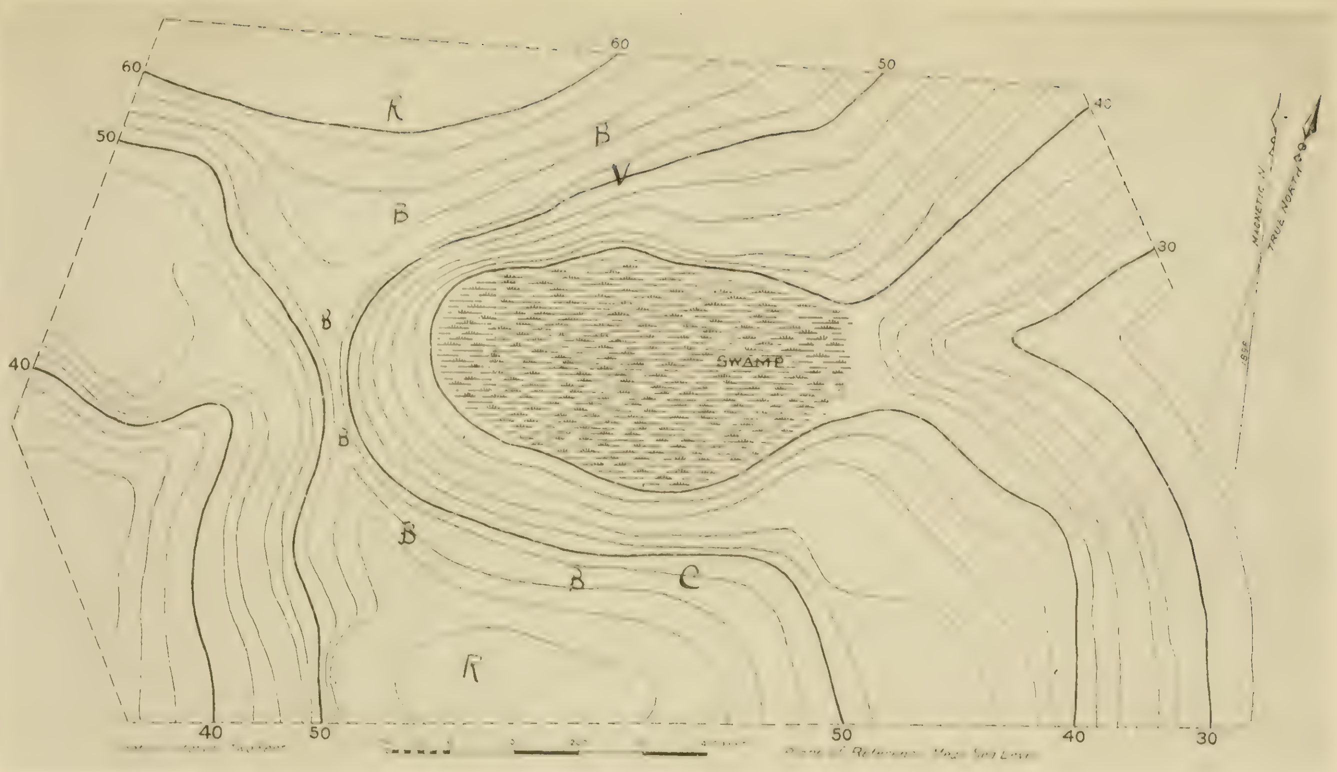
HELIOTYPE CO., BOSTON.

CONTOUR MAP OF THE BEACH (B) REPRESENTED ON PLATE 2.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MAGNETIC N
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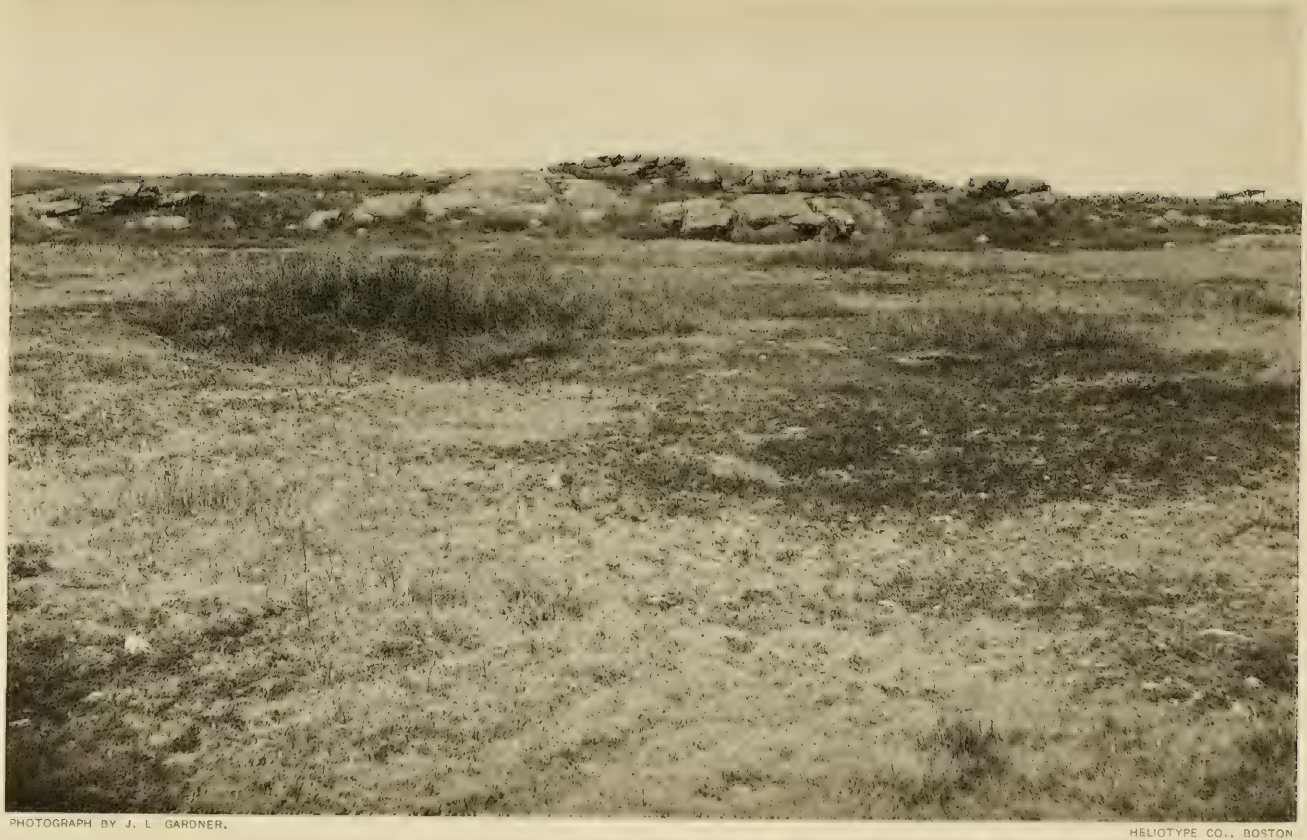
1896

HELIOTYPE CO., BOSTON.

THE ELEVATED BEACH (B B ETC.) AT EASTERN POINT (PL. 1, D), CONNECTING THE BARE ROCK HILLS (R, R,).

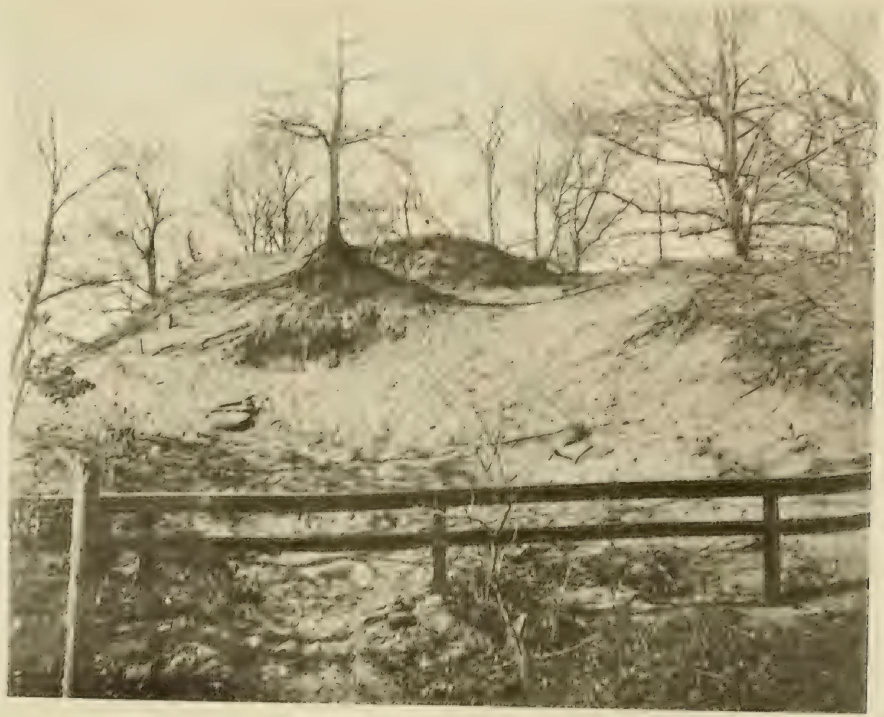


PHOTOGRAPH BY J. L GARDNER.

HELIOTYPE CO., BOSTON

BARE ROCK LEDGE, WAVE-STRIPPED(?) AT EASTERN POINT, LOOKING FROM THE BEACH (PL. 2 AND 3)

THE POSITION OF THIS LEDGE IS INDICATED IN THE NORTHWESTERN CORNER OF PLATE 2.



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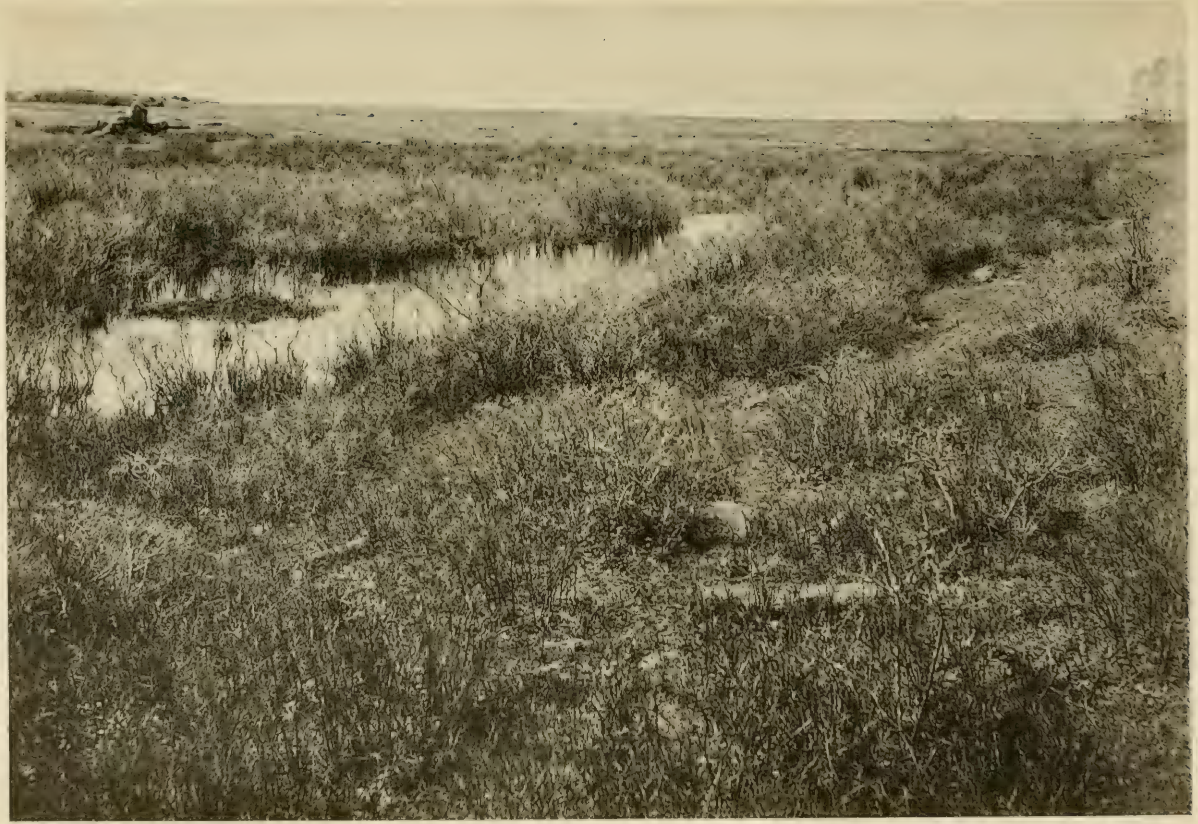
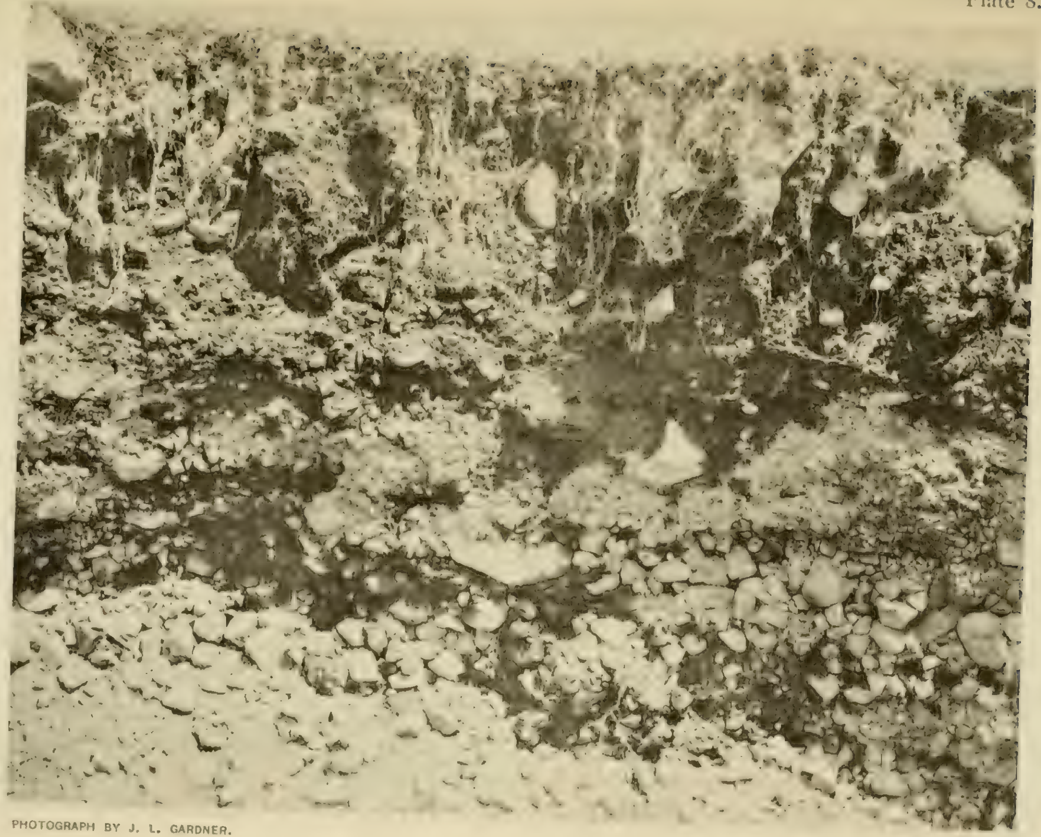
OPEN OAK FOREST IN THE EXTINCT SAND DUNE AREA OF LANESVILLE, MASS. (H IN PL. 1.)



PHOTOGRAPH BY J. L. GARDNER. HELIOTYPE CO., BOSTON.

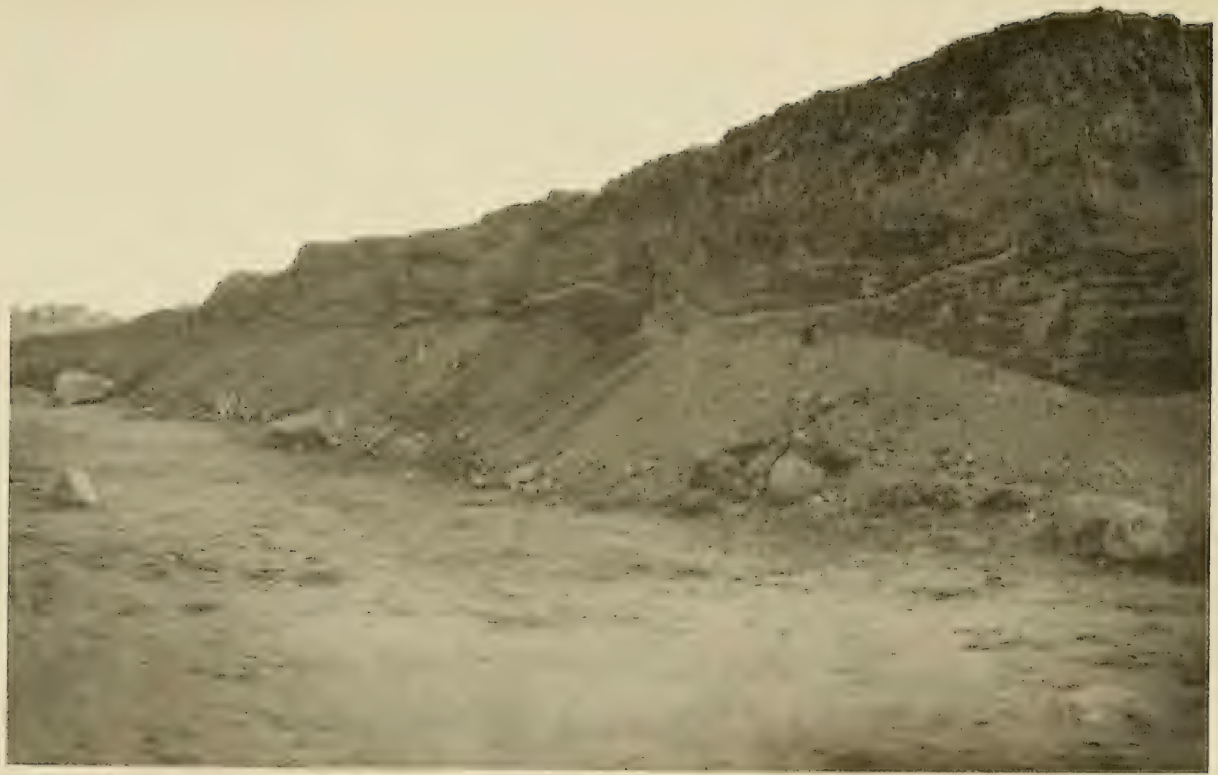
CREST OF THE BEACH (B, B, IN PL. 4), THE LOW ROCK HILLS SHOWING ON THE EXTREME LEFT AND THE SWAMP IN THE FOREGROUND. VIEW TAKEN FROM V, PL. 4.



PHOTOGRAPH BY J. L. GARDNER.

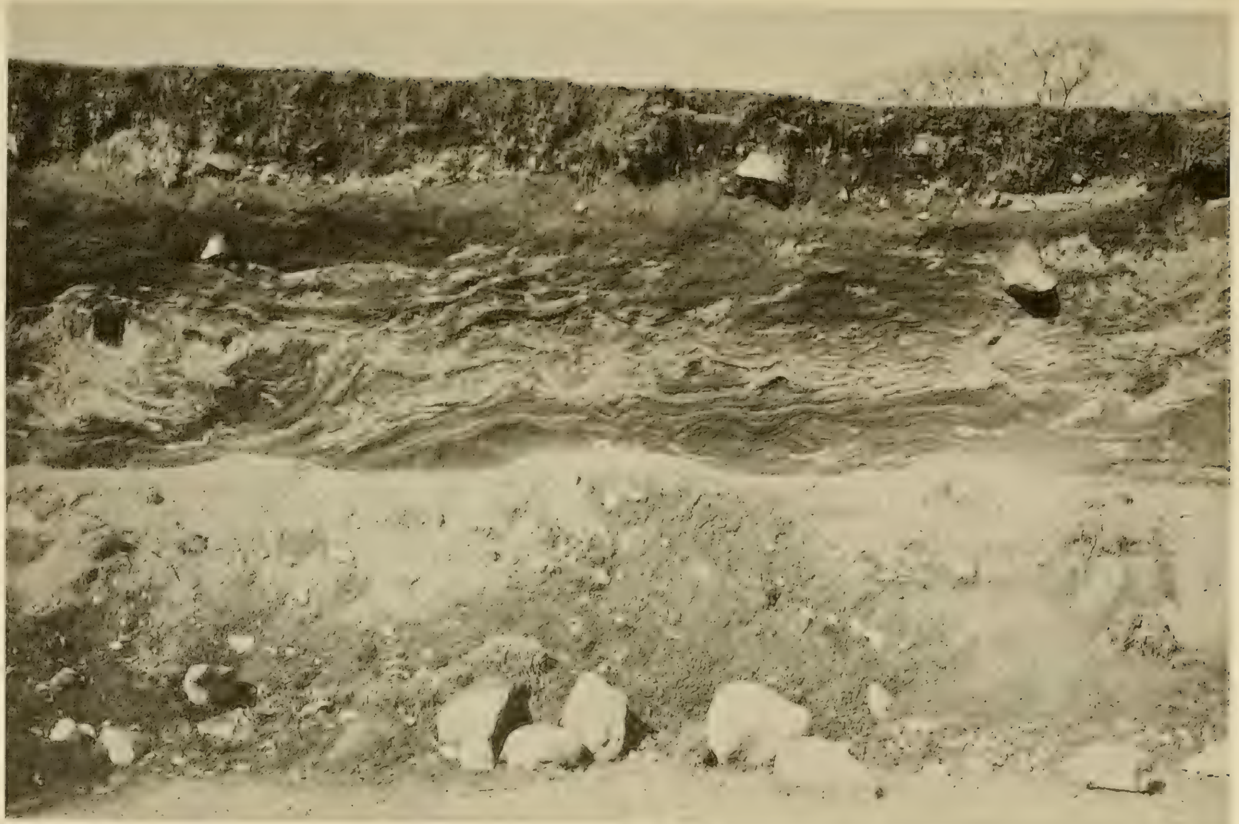
HELIOTYPE CO., BOSTON.

CUT IN THE ELEVATED BEACH (AT C, PL. 4).



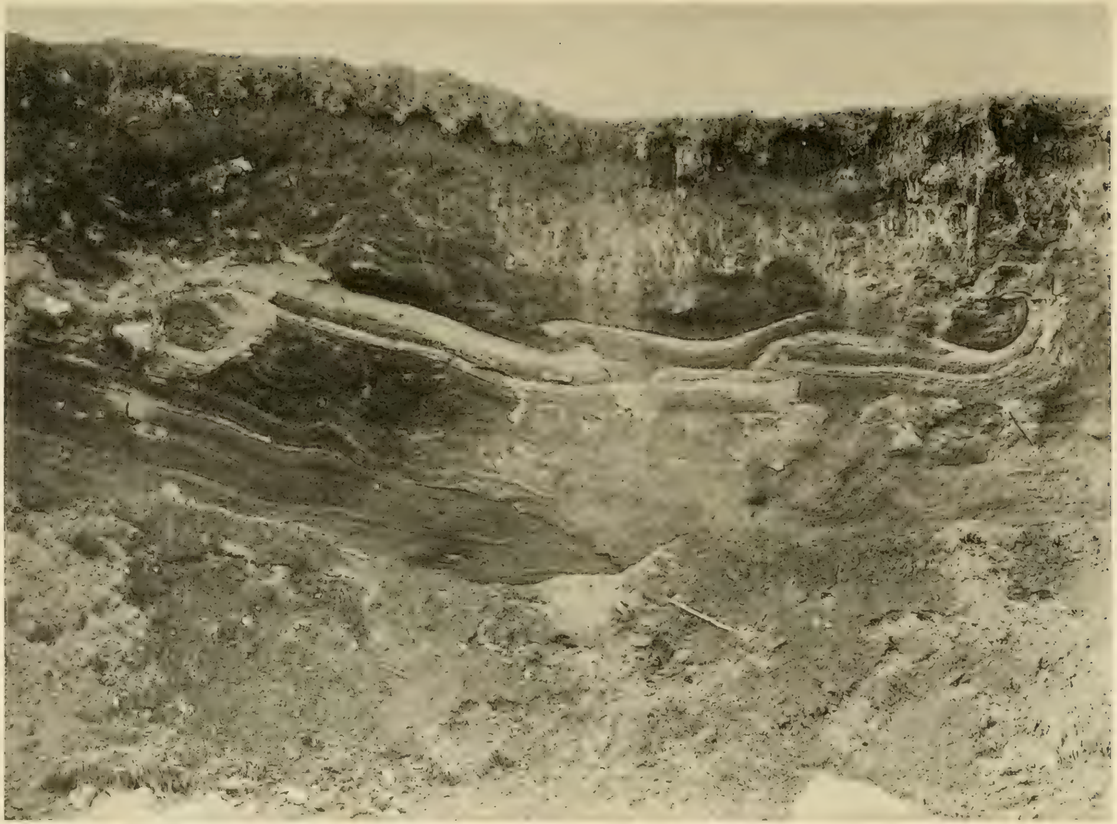
PHOTOGRAPH BY J. L. GARDNER. HELIOTYPE CO., BOSTON.

THE INTERGLACIAL(?) BEDS AT STAGE FORT, GLOUCESTER, SHOWING THE CRUMPLED STRATA.



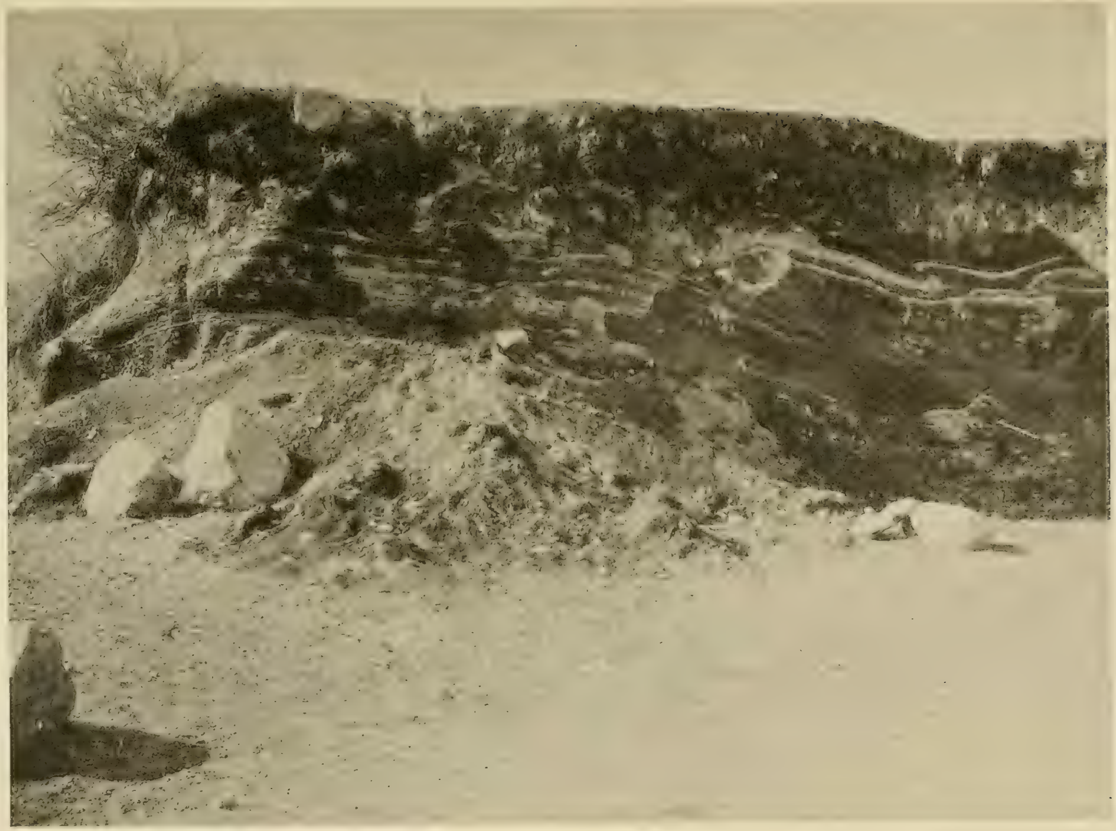
PHOTOGRAPH BY J. L. GARDNER. HELIOTYPE CO., BOSTON.

UNCONFORMITY BETWEEN THE TILL AND THE CRUMPLED INTERGLACIAL(?) BEDS.



PHOTOGRAPH BY J. L. GARDNER. HELIOTYPE CO., BOSTON.

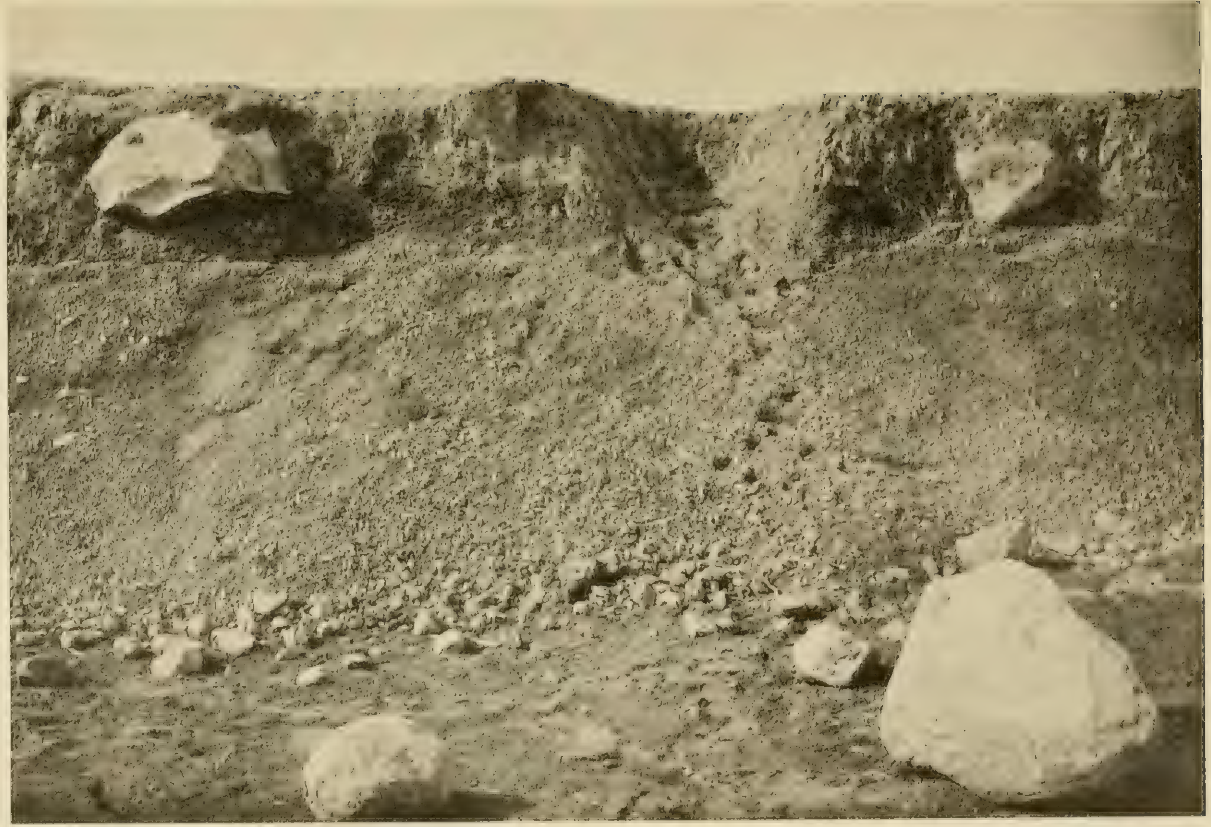
CRUMPLING AND THRUST-FAULTING IN THE INTERGLACIAL(?) BEDS AT STAGE FORT, GLOUCESTER HARBOR.



PHOTOGRAPH BY J. L. GARDNER. HELIOTYPE CO., BOSTON.

GRAVEL LAYER (AT LEFT END OF CUT) BENEATH THE INTERGLACIAL(?) CLAYS, TILL ABOVE.

STAGE FORT, GLOUCESTER HARBOR.



PHOTOGRAPH BY J. L. GARDNER.

HELIOTYPE CO., BOSTON.

LARGE BOULDERS IN THE INTERGLACIAL(?) BEDS. THE TILL HAS BEEN REMOVED FROM THE TOP. GLOUCESTER HARBOR, MASS.

Bulletin of the Museum of Comparative Zoölogy
AT HARVARD COLLEGE.
VOL. XLII.

GEOLOGICAL SERIES, Vol. VI. No. 5.

THE HURRICANE FAULT IN THE TOQUEVILLE DISTRICT, UTAH.

BY ELLSWORTH HUNTINGTON AND JAMES WALTER GOLDTHWAIT.

WITH SEVEN PLATES.

CAMBRIDGE, MASS., U.S.A.:
PRINTED FOR THE MUSEUM.
FEBRUARY, 1904.

No. 5.— *The Hurricane Fault in the Toquerville District, Utah.*

By Ellsworth Huntington and James Walter Goldthwait.

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Introduction.

The district around Toquerville, in the southwestern corner of Utah, is one which offers much for geological study. In a recent number of this Bulletin Professor W. M. Davis of Harvard University calls attention to the problems seen at Toquerville, more particularly to those which concern the northward extension and the disputed age of the great Hurricane fault (*b*, p. 147). A closer acquaintance with these problems was made when, in the summer of 1902, the writers had the opportunity to visit the Toquerville district under the guidance of Professor Davis, and to spend a few weeks there in geological field work.

The course which our party took, and the dates at which we touched certain points in the plateau country have already been outlined in a paper by Professor Davis (*d*, pp. 2, 3). The wagon route led southward from the terminus of the railroad at Marysvale up the Sevier valley, to the divide between the Great basin and the Colorado river. Thence we moved on, following Kanab creek from its headwaters to the town of Kanab, and passing in succession the great series of broad terraces and stupendous cliffs which descend step by step to the Colorado river, one hundred miles away. In this series of steps we saw consecutively the pink Tertiary cliffs, the brown Cretaceous ridges and hills, the snow-white "Jurassic" escarpment, and lastly the blazing "Vermilion" cliffs and the outlying "Chocolate" cliffs of Kanab. From Kanab we journeyed on horseback across the desert platform of Carboniferous limestone to the Grand canyon, at Mount Trumbull, — a place almost never visited by sight-seers and rarely by scientific travellers. Thence, after two days on the esplanade halfway down the canyon, we rode northward nearly parallel to the Hurricane fault and a few miles east of the "Ledge," to the Virgin river at Rockville. Just above the village, near the Temples of the Virgin, at Zion, we saw the slit-like cleft which the river has cut down two thousand feet through the massive red and white sandstone. From here it was but a short day's trip down the canyon to Toquerville, where we made our headquarters during the three weeks in which we were studying and mapping the surrounding region. At the end of a week Professor Davis went on to Nevada, to study there some of the ranges of the Great basin. After the third week one of the writers returned to Salt Lake city, while the other spent two weeks visiting the Colob plateau, the Grand Wash, and the lower end of the Colorado canyon.

The Toquerville district is one where the whole aspect of the country is as varied as its geologic structure. The town is situated at the base of the Hurricane ledge, a high steep escarpment which marks the course of the Hurricane fault and delimits the great plateau region of the east from the broken Basin Range region on the west. The Hurricane ledge proper, running northward from the Colorado river, decreases in height a few miles southeast of Toquerville, and finally, very near the town, dies out; a short distance northwest, however, a new escarpment, locally called Bellevue ridge, continues north nearly in line with the Hurricane. Between the point where the Hurricane dies out and the Bellevue ridge begins is Toquer hill, a connecting link with anticlinal structure. From the top of this hill, just above the town, one looks eastward across the broad plateau country, where prevailing horizontality of surface is not weakened but rather strengthened by the long mesas and terraces with their steep fronts, which display the bare horizontal rock structure with all the emphasis that color can give. On the northeast is the lofty Colob plateau, too far distant to distinguish the smoothly graded slopes of its mature low-mountainous topography; but its conspicuous southwestern flank faces the observer, — a lofty ragged cliff front of red sandstone, the western end of the Vermilion cliff.

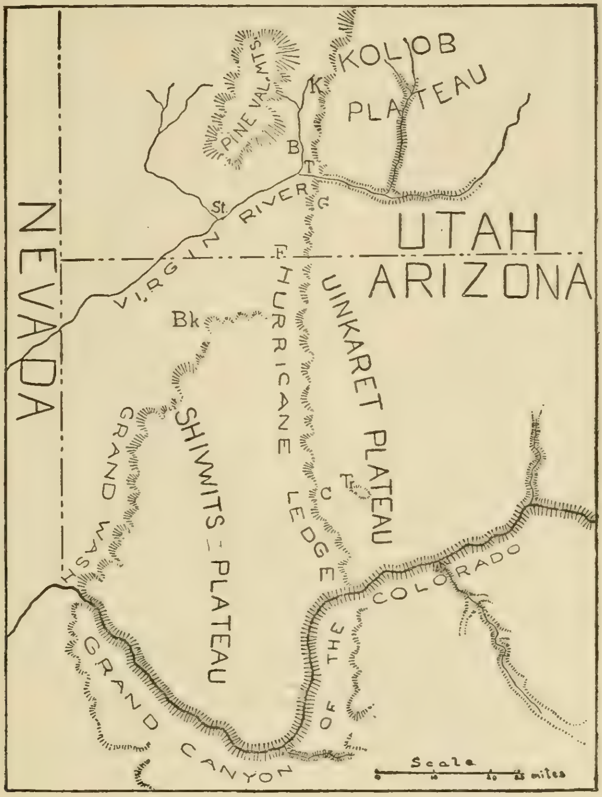

PINE VAL. MTS.
K
KOLOB PLATEAU
B
T
St.
VIRGIN RIVER
G
UTAH
ARIZONA
NEVADA
F
HURRICANE LEDGE
UINKARET PLATEAU
Bk
GRAND WASH
SHIVWITS PLATEAU
Tr.
C
COLORADO
THE TOROWEAP
GRAND CANYON
Scale
0
10
20
25 miles

FIGURE 1.

Sketch-map of part of the region traversed by the Hurricane fault. (From Journal of Geology.) K = Kanarra; B = Bellevue; T = Toquerville; G = Gould's ranch; St = St. George; F = Fort Pierce; Bk = Black Rock spring; Tr = Mt. Trumbull; C = Coal spring.

The step down from this red-rimmed plateau to the Aubrey platform is broken by an intermediate platform and big flat topped mesas of gayly colored shales capped by a resistant conglomerate bed. Beyond them stretches the vast Aubrey platform. Thus, as one looks eastward towards the plateau country, the impression is uniform horizontality. Turning about towards the west, one sees a different country. Instead of the flat plateaus there are low hills of irregular form, and mountain ranges beyond. To the northeast rise the smooth slopes of the Pine Valley mountains, generally subdued in form though already somewhat scarred by recently revived activity of erosion. Between the range and Toquer hill lie foot-hills, whose irregularity in arrangement of colors indicates a rock structure complicated by folding, in contrast to the regularity of color so noticeable in the plateaus to the east. Towards the southwest the view is limited again by the hills about St. George. In the foreground a lowland stretches from north to south, along the base of the Hurricane-Bellevue cliff front. Near this escarpment the lowland is generally flat and is partly buried under lavas, but here and there black basaltic cones show the sources from which these lavas spread out. Northwest of Toquerville two broad alluvial fans stretch out from the Pine Valley range over the lowland, and these, with the lava sheets, conceal the rock structure over a considerable area.

Such, in outline, is the appearance of the district in which we worked. Our main interest lay in the history of the Hurricane fault, and its bearing upon the broader history of the whole plateau region on its eastern side. Of equal interest was the study of its neighbor, the Grand Wash fault, and it is to the evidence along these two fault lines that we wish to direct especial attention. It seems wise, however, before taking up the main theme — the Tertiary history of the region — to consider briefly the earlier history, chiefly Mesozoic.

The Rock Series.

The question of the subdivision of the rock series into formations has always been puzzling. Newberry, Powell, Gilbert, and Howell contributed much towards an understanding of the stratigraphy of the plateau region; but the scarcity of characteristic fossils made it impossible to divide the series satisfactorily into formations on a paleontologic basis. In his elaboration of the work of these men, however, Dutton has sought, both by direct fossil evidence and by rather doubtful correlations with strata in neighboring provinces, to identify several formations as representatives of definite geological periods. For instance, the time-names "Permian," "Trias," and "Jura," which suggest that the geological ages of the formations are well known, are applied by Dutton to formations whose exact ages are still in dispute. Since, therefore, we do not feel ready to accept Dutton's names for the doubtful members of the rock series, we shall follow the present method of the United States Geological Survey, by using only local names, that have no time significance. In an earlier paper on the Toquerville district (p. 48) we used

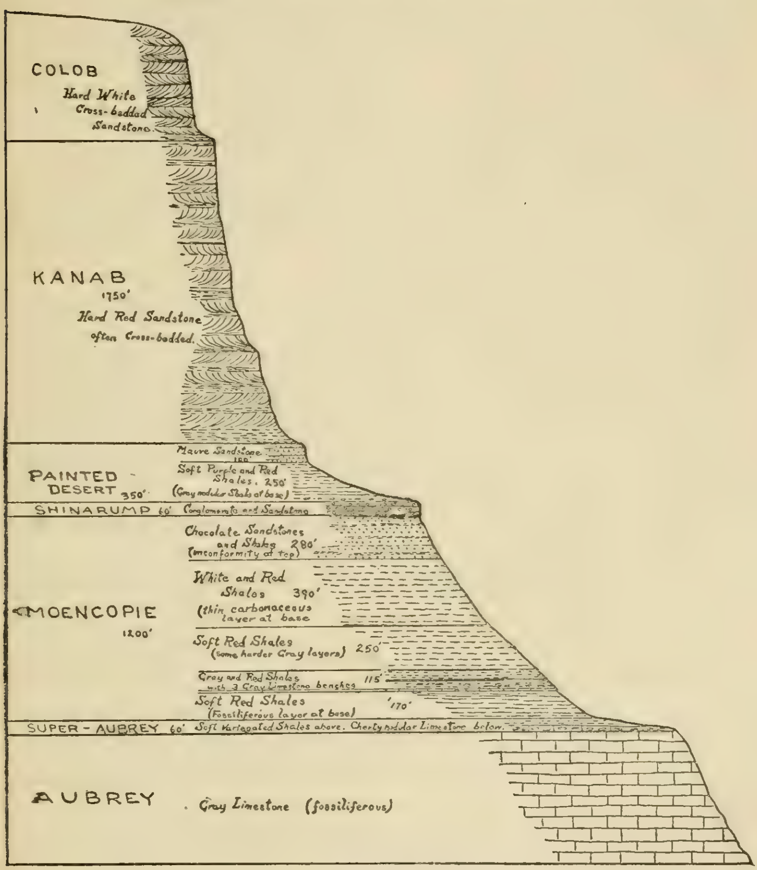

COLOB
Hard White Cross-bedded Sandstone
KANAB
1750'
Hard Red Sandstone often Cross-bedded.
PAINTED DESERT 350'
Mauve Sandstone 100'
Soft Purple and Red Shales. 250'
(Gray nodular Shale at base)
SHINARUMP 60' Conglomerate and Sandstone
MOENCOPIE
1200'
Chocolate Sandstones and Shales 280'
(unconformity at top)
White and Red Shales 390'
(thin carbonaceous layer at base
Soft Red Shales (some harder Gray layers) 250'
Gray and Red Shales with 3 Gray Limestone benches 115'
Soft Red Shales 170'
(Fossiliferous layer at base)
SUPER-AUBREY 60' Soft Variegated Shales above. Cherty nodular Limestone below.
AUBREY
Gray Limestone (fossiliferous)

FIGURE 2.

Diagrammatic cross-section of the rock series, as exposed along Le Verkin canyon, between Toquerville and Colob.

the names "Verkin," "Kanab," and "Colob" in place of Dutton's "Permian," "Triassic," and "Jurassic." Since this paper was written, we have learned that Ward had already given the name "Moencopie" to the "Permian" or "Verkin" shales, and had used "Painted Desert" in a somewhat indefinite way for shales of the "Lower Triassic" or "Lower Kanab." In recognition of the priority of Ward's names, we shall discard the term "Verkin" in favor of "Moencopie," and use "Painted Desert" for the soft sandy "Triassic" shales, restricting "Kanab" to the overlying hard red sandstone. "Colob" will apply, as before, to the cross-bedded white sandstone, — the "Jurassic" of Dutton.

The names Colob, Kanab, Painted Desert, Shinarump, Moencopie, and Aubrey apply to single groups of strata that are perfectly distinct from the other groups, not only in structure but also in outward appearance. Each formation has its characteristic color or group of colors, and under erosion assumes forms peculiar to itself.

The colors of the rocks among the plateaus are a revelation to one who has seen only the neutral shades of the ledges in a region of granite gneisses and schists, or the soil-covered outcrops of a forested region. In the lofty buttes and bare rock-walls of the plateau country, one sees a most astonishing display of color, ranging from dull neutral shades of gray and brown on the one hand to delicate pink, rich chocolate, intense brick-red, or pure white, on the other.

Wherever the color changes, in passing from one formation to the next, a complete change in the texture and structure of the rock results in an equally definite change in the shapes developed by erosion. A formation of soft shales may weather down into a long slope, passing below into a flat sandstone shelf that ends sharply in a sandstone cliff. Looking across the canyon of the Virgin river at Rockville, for example, the observer sees a terrace of brightly colored Moencopie shales beneath a dun-colored Shinarump cap, while beyond the hard platform of the latter, and above it, rise gigantic towers and cliffs of a sandstone that looks fairly red-hot.

A few words about each of these formations will serve to give an idea as to the way each looks in the field.

The Aubrey formation, in the Toquerville district, consists of a rather massive gray limestone, capped by a series of colored shales. The limestone resists erosion with much strength. Where it has been cut by the recent Hurricane fault, it stands up as a steep ragged wall. All along the face of the Hurricane its structure shows plainly, even at a distance, in well-defined lines of light and shade that mark the hard beds from the soft. Every sag in the beds shows itself in a curved line. East of the fault scarp, the Aubrey stretches away as a broad platform, which for miles has been swept clean of the overlying Moencopie shales. It extends from Toquerville clear to the Grand canyon, — a vast yellow dust-covered plain, thinly drained by dry-washes, with here and there a low limestone ridge, a black basaltic cone, or a highly colored Moencopie mesa.

The Moencopie shales, when protected by the strong Shinarump cap, stand up in broad ragged mesas that are remarkable for both color and sculpture. From the top of one of these tables to the plain at its base, the bare slopes descend very steeply, with an occasional narrow bench, limited by a cliff, where a harder member asserts its strength. Seen from a distance, the alternating horizontal bands of chocolate, gray, lavender, and red stand out with ribbon-like uniformity and distinctness. In contour these tables are very irregular, with long headlands and re-entrants, down the slopes of which are cut innumerable gullies and ravines, systematically placed, so as to form a minute pattern of tapering, branching, and sprawling spurs, that give the impression of a conventional design. Where the shales have lost their conglomerate cap, however, they have either been dissected into a choppy bad-land topography of gullies and ridges, or, as is more often the case, they have melted away into broad, gently sloping grade plains, which stretch out from the escarpment for miles, until at last they merge into the Aubrey platform.

In sharp contrast to the weak Moencopie shales below and the soft Painted Desert shales above, the Shinarump stands out firmly as a bench and cliff maker. In the eastern part of our area, among the plateaus, it forms the flat top of the "Permian" terrace, and its outlying tables. Not uncommonly its edge projects out over the soft shales beneath, like an ornamental moulding. Often, where it is the uppermost member remaining, its top is flat and clean ; but where it merely flanks the bold Kanab escarpment, its platform is banked by landslides from above. This is well shown at Rockville, near the Virgin river, where the waste of the shales is particularly rapid (Plate 4 B).

Where the strata have been folded, the Shinarump again is conspicuous. Between Toquerville and St. George, where a great plunging anticline has been unroofed by erosion, the conglomerate forms a cigar-shaped hill, splitting at its southern end so as to surround a long amphitheatre (Plate 2 B).

In Bellevue ridge, where the series from Aubrey to Kanab are tipped up rather steeply with an eastward dip, the Shinarump forms a sharp monoclinal ridge or cuesta (see Fig. 3). We climbed this ridge near Dry canyon. From the base of the Hurricane, up through the super-Aubrey and Moencopie formations, the general slope was never far from thirty degrees, though it was broken occasionally by minor ridges and hollows, where harder members of the Moencopie showed their edges or softer ones had worn away. Toward the top of the shales, however, the slope became steeper and more difficult to climb, until on reaching the Shinarump we found a high cliff that could be scaled only in a few places. Along the greater part of this Shinarump edge, the hard conglomerate projected out over the shale talus, showing how active was the sapping process beneath it. Eastward from the crest there was a long back-slope, down the top of the conglomerate, to a longitudinal valley that had been worn out on the overlying sandy shales.

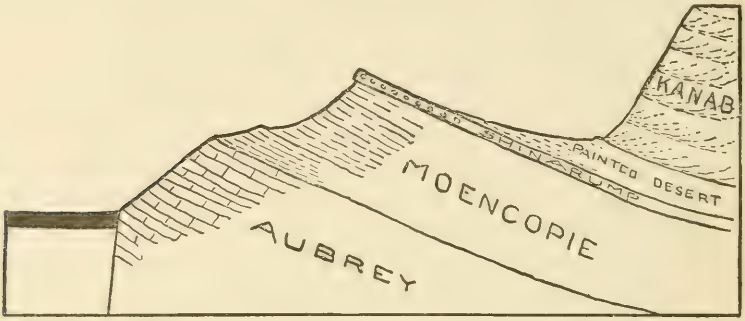


FIGURE 3.
Bellevue ridge near Dry canyon.

The Painted Desert formation is a series of shales, elsewhere chiefly clay-shales, but in the Toquerville district more sandy. Although varied in color, they are uniformly weak. Along the Vermilion cliffs, and particularly in the canyons, where revived erosion is most active, the rapid retreat of the shales has induced a general undermining of the overlying hard Kanab sandstone, giving a hummocky landslide topography that is quite different from any other surface form in the region.

At the top of the Painted Desert series, as we have limited it, and at the base of the Kanab, there is a thick sandstone member, of a lavender or mauve color, and of such hardness that it often forms a bench above the shales, after the manner of the Shinarump, though hardly so conspicuously. In Plate 1 A this bench-maker can be seen, near the base of the lofty Temples of the Virgin. Plate 2 A shows it again, this time at Dry canyon, where as a result of tilting it forms a cuesta parallel to the Shinarump ridge, and just east of it.

Above the mauve sandstone, at the base of the Kanab, is a thin series of weak beds, whose non-resistance permits the development of the platform beneath; then comes about seventeen hundred feet of uniformly hard brick-red sandstone, occasionally cross-bedded. It is the unusual thickness and massiveness of this hard sandstone formation that makes it the greatest cliff-builder in the region. As the northwestern portion of the Vermilion cliffs, it runs just outside the limits of our map; for although at Rockville its imposing front trends towards Toquerville, it turns rather sharply, a few miles east of LeVerkin creek, and runs northwest to Colob. The architecture of the Kanab is massive and grand. Lofty though the red cliffs really are, their height is even exaggerated, as a result of prominent vertical jointing, by deep rifts which cut the cliffs from top to bottom. Below, the rifts show as sharp upright slits through the rock, but at the top they widen out into ragged gashes, chopping up the rock into pinnacles and spires (Plates 1 B, 4 B).

Within the limits of our map the Kanab does not attain this grandeur of form. Only along the eastern base of the Pine Valley mountains is the entire formation exposed; and there it has an ancient subdued topography that has had little chance for reconstruction through a renewal of slopes, as will be shown later.

The Colob formation, also, in the vicinity of Toquerville, is not displayed to best advantage. Along the Pine Valley range it forms rounded foot-hills and long sloping ridges, which have little individuality, aside from their pure white or occasional buff color. Far to the eastward, at the Temples of the Virgin, and along the marvellous White cliffs, the more magnificent features of sculpture are brought out by active erosion (Plate 4 A). Even in our region, however, where recent erosion has been actively at work, the structural detail of the Colob is well shown, in long sweeping curves of cross-bedding. The slow crumbling away of the fine white sand grains brings out the frost-work pattern in a way that is at once pleasing and grotesque. The mysterious name Colob is well suited to it.

The Cretaceous and Tertiary formations are of little importance in the region in which we worked; for only on the eastern flank of the Pine Valley mountains did we see them exposed in entirety, and the remoteness of this part of the region from the Hurricane fault line, together with the evident simplicity of structure of the range turned our attention away from this part of the rock series. On Colob the light brownish Cretaceous sandstones, limestones, and shales occur, and coal beds are associated with them. A small patch of Cretaceous is exposed in the canyon of Ash creek not far below Toquerville, but in general the remnants of both the Cretaceous and the Tertiary on the downthrown western side of the fault are concealed beneath lavas. Of the Tertiary beds, which are mostly weak shales and limestones, one member, a coarse quartz-pebble conglomerate, is prominent here, in that it furnishes quantities of quartz cobbles and pebbles which make up a noticeable part of the recent gravels of the district.

Geographical Conditions under which the Strata were deposited.

The geographical history of the Plateau province during the long period from the Devonian era to the end of the Eocene has been well described by earlier observers, who state that it is characterized by deposition under slowly changing conditions which were uniform over a large area. The best account of the region is that of Dutton, of whose conclusions a brief summary will be given. After that a few points will be discussed where further study suggests that during Triassic and Jurassic times land conditions may have lasted longer than has been supposed.

Devonian and Carboniferous Deposition. During the Devonian era or perhaps earlier, at the end of the second long period of erosion of which evidence is found in the walls of the Grand canyon, the sea advanced upon an early Paleozoic or Archæan surface of small relief. After the Tonto sandstones and shales had been deposited upon this, the Lower Carboniferous or Red Wall strata of quartzitic sandstone were laid down in gradually deepening water which in time became deep enough for the deposition of the heavy Upper Red Wall limestone.

"The lower Aubrey group corresponding to the coal measures is a series of sandstones of exceedingly fine texture and often gypsiferous. There is a notable absence in these beds of signs of very shallow water. . . . On the other hand there is no reason to suppose that the depth was at all profound" (*c*, p. 210). "In the upper Aubrey series we come upon some indications of shallow water, and from the base of the Permian upwards these are ever present. In the Permian, Trias, and Jura we find instances of . . . peculiar unconformities by erosion without any unconformity of dip in the beds. Perhaps the most widely spread occurrence of this kind is the contact of the summit of the Permian with the Shinarump conglomerate, which forms the base of the Trias. Wherever this horizon is exposed this unconformity is generally manifest. Between the base of the Permian and the summit of the Carboniferous a similar relation has been observed in numerous localities, and there is a similar instance in the lower Trias. It has also been detected between the Trias and Jura, and between the Jura and Cretaceous" (*c*, p. 211). "During the entire [Mesozoic] age the surface of deposition was always very near the sea-level. The proof of this is abundant and clear. Throughout the Plateau province the strata are all shallow water deposits. Fossil forests, ripple-marked shales, frequent unconformities by erosion without discrepancy of dip, cross-bedded sandstones, occasional retirements of the waters, all mark very shallow water in the Permian, Trias, and Jura; while coal, carbonaceous shales, abundant remains of land plants indicate the same for the Cretaceous. And finally, the absence of all traces of appreciable displacement except along the coasts combines to prove that the Mesozoic beds were deposited with almost rigorous horizontality, and very nearly at sea-level, throughout the entire Mesozoic" (*c*, p. 69). "Now and then the waters retreated from [the surface of deposition], but only for very brief periods. On the whole deposition proceeded almost continuously" (*c*, p. 211).

"From six thousand to fifteen thousand feet of strata were deposited over an area of more than one hundred thousand square miles with comparatively few unconformities and contemporary disturbances, while the level of the uppermost stratum remained at sensibly the same geographical horizon. . . . The case is analogous to that of the Appalachians during Palæozoic time," and the conditions during the western Cretaceous are especially like those of the eastern Carboniferous. "The more we reflect upon the similarity the stronger does it become. It fails, however, when we come to reflect upon the phenomena presented in the two regions in the period subsequent to the deposition; the Appalachian strata were flexed and plicated to an extreme degree, while those of the west are for the most part calm and even. Only in the vicinity of the mountains and shore lines do we find them much disturbed" (*a*, p. 13). All the Mesozoic beds are remarkably uniform in thickness, lithological character, and minute structure such as cross-bedding over the whole great plateau area from the Pine Valley mountains to Western Colorado, and from the middle of Arizona to the southern margin of the Uintas. They are thicker on the edges near the old shore line, and diminish quite rapidly for two or three leagues, but after that the diminution is very slow (*c*, pp. 47, 48, 208).

During the beginning of the Tertiary marine deposition continued in many places, but soon the region was elevated and vast lakes were formed. Sedimentation continued in these to an enormous extent, although gradually the lakes were filled or desiccated, those at the extreme south becoming dry first and those at the north near the Uinta mountains persisting longest (*a*, pp. 216–219).

The main outlines of this history, as thus summarized from Dutton's account, have been placed beyond a doubt by the painstaking work of the earlier observers. When they wrote their reports geologists were only beginning to understand that it is possible for thick and extensive deposits to be laid down on land without the intervention of large bodies of water. Accordingly they assumed that all the Paleozoic and Mesozoic strata of the Plateau province were marine, and the Tertiary strata lacustrine. Professor Davis (*a*, p. 373) has raised the question whether these may not be only in part lacustrine, while perhaps a larger part were deposited subaerially in the form of fluviatile fans, deltas, and flood plains. As Tertiary strata occur but scantily in the Toquerville region and are only of Eocene age, their history will not be further considered. Nor will Paleozoic history be considered, since we have no data beyond those which were available to Dutton. Although the cross-bedded sandstones in the lower part of the Aubrey remind us of the need for further study, there is no reason for doubting the main conclusion that most of the Devonian and Carboniferous strata were deposited in a sea of moderate depth. The Moencopie series was probably laid down in a shallow sea where estuarine conditions may possibly have prevailed, as is indicated by the intercalated layers of gypsum, and the almost total lack of fossils in strata admirably adapted to their preservation had they existed.

THE SHINARUMP LAND. At the close of the Permian, or Moencopie, the sea retired (Dutton, *c*, p. 211) and the greater part of the Plateau province was exposed as a plain with a slope so slight that but very little erosion took place. Plants covered this plain, at least in those parts where we saw the unconformity, as is shown by the layer of carbonaceous matter lying just below the surface of that time. The Shinarump conglomerate lying just above has been supposed to indicate an immediate return of the sea. There is another possibility, however; and we should like to raise the question whether this may not be a continental deposit which was gradually built outward from the former shore line of the Moencopie sea. It seems as though when, at the beginning of the Shinarump period, the former sea bottom was so far elevated as to become a low coastal plain, the land must still have continued to pour upon it countless streams of waste which would have spread out in the form of very gently sloping confluent fans. If such deposits were formed they would be comparable to those now forming in the low plains of northern India (Blanford, pp. 382–389) and the high plains at the eastern base of the Rocky mountains (Johnson, pp. 613–622). The very fact that the Shinarump is more or less conglomeratic in all parts suggests a subaerial origin. In the ocean it is hardly probable that pebbles even though small should be carried a hundred miles directly out from the shore and scattered evenly over a hundred thousand square miles of the sea bottom. Yet such must have been the case if the Shinarump is a marine deposit. If, on the other hand, it is a subaerial deposit the pebbles are just the sort of small bits of quartz that would gradually be washed farther and farther out over the plains by streams descending out of the mountains. A still stronger suggestion of land conditions is found in the arrangement of the sand and gravel of the formation. In Toquer Hill, for example, we have a coarse sandstone with streaks of quartz conglomerate, sometimes forming long regular bands of pebbles ranging up to an inch in diameter, at others composed of little flinty pebbles scattered through the sandstone at long intervals. Still again it forms old stream channels with distinct lateral unconformities, or caps the truncated edges of a series of cross-bedded sandstone layers. Cross-bedding on a rather large scale is common. Near the top of the Shinarump petrified wood is abundant, and we found one complete trunk sixty feet long. The lateral unconformities and cross-bedded strata capped by horizontal conglomerate beds are difficult to explain except as a result of stream action. The petrified wood has been supposed to have been floated into the sea from distant shores and to have become water-logged and to have sunk in all parts of the plateau province. If this is the case it is difficult to see why the wood is confined so strictly to this particular horizon at the top of the Shinarump. The land must have been forested both before and after the time represented by this formation, and there must have been winds and currents to carry the tree trunks. If the Shinarump is a continental deposit, the difficulty disappears. On the first emergence of the land above sea-level vegetation would be lacking. Therefore the lower Shinarump would contain no fossil wood. Later the whole country would become forested and many trees would be buried under fluviatile deposits. Lastly, when the sea again encroached upon the land the whole forest would be buried in the new marine sediments, and we should find, as is the case at Toquerville, that this particular layer would be especially rich in fossil wood.

One hundred and fifty miles southwest of the region that we have been discussing, Ward in his study of the district around the Little Colorado river has found similar and even more marked indications of land conditions. The Shinarump formation there increases to a thickness of sixteen hundred feet, and is characterized throughout by fossil wood and other signs of terrestrial origin (p. 405). The conglomerate "contains somewhat large, but always well-worn pebbles and cobbles derived from underlying formations; still it rarely happens that this aspect of the beds forms the major part of them. In the first place the conglomerate tends to shade off into coarse gravels and then into true sandstones. These . . . are always more or less cross-bedded and usually exhibit lines of pebbles running through them in various directions. . . . Although the sandstones proper generally occur lower down, still there is no uniformity in the arrangement, and sandstones are often found in the middle and conglomerates more rarely at the top." In addition to these the Shinarump (p. 406) embraces other classes of beds, chiefly well-stratified thinnish sandstone shales which often thicken in short distances and become transformed into bluish-white marl. In the lower valley of the Little Colorado, where the Shinarump conglomerate is only three hundred feet thick, this feature is not prominent, but elsewhere, as in the Petrified Forest region where the formation attains a thickness of seven or eight hundred feet, "this tendency on the part of certain beds to become transformed into marls is the most marked feature of the formation. . . . These heavy marl beds . . . are interstratified between conglomerates, coarse gravels, and cross-bedded sandstones. . . . These varying beds . . . often change the one into the other even at the same horizon within short distances" (p. 406).

Overlying the conglomerate proper are the Le Roux or Belodont beds of variegated shales in which Ward (p. 407) has found numerous remains of terrestrial vertebrates. These too "are found stratified between the sandstones by the transformation of certain shales into marls. If these beds are carefully traced a short distance in the direction of the dip, they will be seen to thicken very rapidly and soon to take on the character of true variegated marls" (p. 409). They start beneath a bed of sandstone which thins out to nothing when followed horizontally, while at the same time the marl beds thicken greatly and overlap upon beds of conglomerate. In brief the Shinarump here consists of beds of very varying coarseness which merge into one another, thicken rapidly, or die out with the greatest irregularity. In addition to this many layers consist of cross-bedded sandstone, others are marly, and still others contain irregular trains or layers of pebbles. Lastly, the whole formation is full of petrified wood, and part contains the fossil remains of land animals. All these conditions are unlike those of ordinary marine deposition, but are exactly what we should expect in continental deposits laid down by streams or in occasional lakes.

The thin Shinarump deposits near Toquerville and the thick formation which occupies a corresponding position near the Little Colorado river both show a rapid thinning of the strata toward the great central plateau region. This is what would naturally be expected if the deposits were subaerial. In the central region, however, to judge from the reports of Dutton and others, the Shinarump seems to have a uniform thickness over a large area. Such uniformity is characteristic of marine deposits, and it may be that part of the Shinarump is marine. It is possible, however, that part of the formation was laid down by a retreating or oscillating sea, or that the strata were laid down in a shallow basin the centre of which was so far from the source of supply that the streams could not bring to it more than a few feet of sediment, which they distributed with considerable uniformity. As yet we have not sufficient evidence to justify us in saying that the Shinarump as a whole is either marine or non-marine. It is an open question, but the weight of evidence seems to indicate that in part at least it is non-marine.

THE PAINTED DESERT PERIOD. Although the Painted Desert strata which succeed those of this doubtful land period contain no fossils, they are supposed to be the result of marine deposition. They are evenly stratified and continue unchanged for long distances. They consist of soft sandstones, thin in our area, but nine hundred feet thick along the Little Colorado river.

The Kanab Period. In the regions far from the coast uniform conditions may have prevailed unbroken to the end of the Mesozoic. Near the shore, however, there was a break at the beginning of the Kanab period, as is shown near Toquerville by a bench-making layer of mauve sandstone one hundred feet thick in which the strata are strongly cross-bedded on a large scale. Throughout the overlying massive red sandstone there is an alternation of cross-bedded and horizontal strata, suggesting that during the long period of their formation there was a constant change of conditions. Although conditions of uneven deposition, like those which will be discussed in connection with the succeeding Colob formation, prevailed to a great extent and caused the cross-bedding, there seem to have been shorter times of even deposition like that of the Painted Desert period.

The Colob Period. The Colob period, which follows the indeterminate Kanab, seems to be unique in geological history. Its strata, like those of the Shinarump, have been tacitly assumed to be of marine origin, and there has been little or no attempt to account for their peculiar features. A study of these leads us to query whether this too may not be of continental origin. The Shinarump suggests a piedmont deposit formed during a time when many streams flowed out upon a coastal plain, and when the climate was moist enough to allow the growth of forests upon the lowlands. The Colob suggests a piedmont deposit formed during a time when the climate had become so dry that a great desert drifted its sands in huge dunes over an area as large as the state of Indiana.

In the lofty plateau east and northeast of Toquerville the strata are but slightly tilted, and fine vertical sections are exposed in the steep walls of numerous narrow canyons. The best example of these that we saw is Kanab canyon, although the same features are almost as well displayed in several other places. Here the white sandstone is cross-bedded on a scale so large that a single layer attains a thickness of from five to fifty feet. Most of these layers have a very persistent and uniform dip of twenty or twenty-five degrees varying in direction from southeast to southwest. Other directions of dip are seen, but they seem to be rarer and less steep. The top of every inclined bed is smoothly truncated by what at first seems to be a horizontal layer, from which rises a new cross-bedded series. It is remarkable, however, that in every case where the strata were closely examined this apparently horizontal layer proved to consist of the lower portions of the overlying inclined strata, which, as they approach the underlying plane of truncation, assume a curve tangent to it, and finally die out as they become horizontal. Everywhere the deposit consists of uniformly fine white sand without a trace of pebbles or of coarser sand so far as has yet been observed. The uniformity of texture is emphasized by the total lack of ripple marks, which, as Cornish (*a*, p. 280) has shown, result from the mixture of sand grains of different sizes. That such a formation could be due to marine or lacustrine action of any kind seems contrary to what we know of such agencies. It is generally recognized that cross-bedding of a marked type is a proof that the deposits were formed close to the shore or on land. The uniform thickness of the Colob sandstone over so great an extent renders it antecedently improbable that it is a shore deposit; the total absence of ripple marks, rill marks, and other characteristic shore features lends support to this, and lastly the perfect smoothness and horizontality of the planes which truncate the tops of the strata render this still more improbable. At the time of the formation of a given cross-bedded layer which is now fifty feet thick and has a dip of twenty-five degrees, the water would have had to be over fifty feet deep, since in their untruncated condition the strata must have had a greater thickness than at present. The question then becomes: Is it possible that in a body of water sixty or more feet deep the waves or tides or currents should first carry away five or ten feet of sand, and then without disturbing the perfectly smooth surface thus formed lay down on it other layers of sand having a dip of twenty degrees and rising fifty or sixty feet above the base on which they were deposited? And could this process go on uninterruptedly over an area of thousands of square miles? We cannot affirm that it is impossible, but we can affirm that it is improbable, and nothing of the kind seems to have been observed in actual formation. The same facts of structure, together with the total absence of gravel, of fossil stream beds, and of lateral uncomformities render it equally improbable that the Colob was deposited by fluviatile processes. The only remaining possible agent is the wind. We cannot yet be certain that the Colob sandstone is a wind formation; nevertheless none of its characteristics seem to oppose such an hypothesis. The uniformity and fineness of the component quartz grains, the steepness of the cross-bedding, its general uniformity with interesting minor variations, the even truncation of the successive cross-bedded strata, and the tangency of the overlying layers to the plane surface thus formed suggest a series of great white dunes marching forward to the east and south from the base of the Basin Range mountains. Far to the southeast the Colob sandstone grows thinner (Ward,

p. 412), and in New Mexico dies out or is merged in the underlying Kanab formation (Dutton, *c*, p. 37, *a*, p. 152). Much further observation is needed before we can arrive at a settled conclusion, but meanwhile it seems to be a fair question whether the cross-bedded strata of the Kanab and Colob formations may not be continental deposits laid down by the wind.

At the end of the Colob period the encroaching Cretaceous sea buried the desert, if desert it really was, and preserved a series of strata which to-day present some of the most magnificent scenery in the world. The upper Kanab canyon with its weird tracery, where the wind has brought into strong relief every line of the criss-cross laminæ; the Temples of the Virgin, where great snow-white domes, turrets, and buttresses rise thousands of feet above the valleys; the gleaming rounded masses of the Colob plateau, standing in sharp contrast to the immense red precipices below them and the green wooded plateau and blue sky above, — all these and many other wonderful scenes we owe perhaps to a great dreary desert of long ago.

SUMMARY. In reviewing the physical history of the Plateau province from the Devonian to the end of the Eocene, as revealed in the strata of the Toquerville region, it appears that on the whole it was a time of slow and steady depression during which deposition was almost uninterrupted. The surface of deposition stood close to sea-level all the time. There were two chief periods of quiet marine deposition, separated by a period of very uneven deposition. This latter was divided into two parts separated by a relatively brief interval of quiet deposition. The first period of uneven deposition was characterized by great variation in the texture of the materials deposited and in the manner of their deposition, and by the preservation of terrestrial fossils. The second was characterized by remarkable uniformity in the texture of the materials and in the manner of their deposition. Arranged in tabular form, the chief periods are as follows: —

1. The long interval between the Devonian and the end of the Moencopie was distinctly a marine era of even deposition, although the lower beds of the upper Aubrey are somewhat uneven.

2. The period of uneven deposition lasts from the beginning of the Shinarump to the end of the Colob. It may be subdivided into three parts: —

A. The Shinarump proper and the lower half of the Le Roux were a time of great diversity in deposition. Coarse gravels and marls were deposited side by side; lateral unconformities, fossil stream beds, and frequent cross-bedding indicate that the water in which the strata were deposited was moving rapidly in flowing streams or shallow lakes; fossil trees and the bones of terrestrial animals show that land cannot have been far away. Many things suggest that this was a period when the country was elevated above the sea and supported abundant life, both animal and vegetable.

B. During the upper half of the Le Roux there was a return to conditions of even, probably marine, deposition, which continued to prevail during the following Painted Desert period.

C. The next periods, the Kanab and Colob, are unique because of the great unevenness with which the strata are bedded and the remarkable uniformity of the sand which composes them. This seems to have been a time when no life flourished. Possibly the deposits are terrestrial and are the product of wind action in a great desert.

3. At the end of the Jurassic and beginning of the Cretaceous a marine phase of even deposition again prevailed for the last time, but after the Cretaceous was fairly under way it passed into the alternating estuarine and swampy conditions under which the coal measures were deposited.

4. Lastly, came the Tertiary with its conditions of uneven terrestrial deposition, which have continued down to the present.

In regard to climate the formations, so far as land indications are concerned, suggest that from Carboniferous onward there was an increase in aridity culminating in the arid conditions which produced the Colob desert. Then the climate grew more moist and equable, so that many plants and animals flourished during the Cretaceous and Tertiary periods. Changes of all kinds took place slowly and on a large scale.

The First Uplift.

The various writers on the Plateau province agree that the long period of quiet deposition extending from Devonian to Eocene times gave place at the end of the latter to an era of exactly the opposite character, marked by great earth movements, extensive vulcanism, and prolonged erosion. The phenomena of the Toquerville district agree perfectly with this, and add some details which have not before been placed on record.

VULCANISM. At the end of the Eocene or early in the Miocene, when as yet erosion had made no noticeable impression upon the strata of our area, and perhaps even while they were still under water, volcanic eruptions began to occur. In the very southwest corner of Utah a great mass of andesite and trachyte was poured out, the remains of which now form the Pine Valley mountains and some small hills northwest of Toquerville. The Pine Valley lava lies upon the youngest Eocene strata in a gentle syncline, which may have been formed either before or after the extrusion of the lava, or may be due in part to the bending of the strata under the weight of the extruded mass. The smaller andesitic hills near Toquerville are either intrusive portions which never reached the surface, or stocks of extrusions of which all other traces have now been removed. This lava seems to be of nearly the same age as the oldest of the successive flows that took place in the region of the High Plateaus farther northeast (Dutton, *a*, pp. 59, 180). Its relation to the flexing and folding to be described in the following paragraphs is uncertain. The fact that the lava covers a surface where little or no trace of erosion has been observed makes it seem probable that the volcanic material was extruded before the flexures and folds were completed. The latter are of great size, and, if accepted theories are correct, required a long period for their completion. Moreover, the flexures are of such a nature that the Toquerville region must have been elevated some thousands of feet above sea-level. At the close of the period of folding, therefore, the sedimentary strata underlying and surrounding the Pine Valley mountains must have been exposed to erosion for a considerable length of time, unless they were in some way protected. If the lava was not extruded till after the completion of the folding, the surface of the Eocene strata ought to show considerable erosion. Wherever the contact of the Eocene and volcanic formations was observed there was no evidence of such erosion. The observed localities, however, were so few, and the contact was so often covered with talus, that no positive conclusion can be drawn. We may provisionally conclude, then, that this oldest lava of our region was extruded before or during the period of flexing and folding which we shall now discuss.

FLEXING AND FOLDING. This folding is a feature peculiar to the area immediately around Toquerville. East of a line drawn along the southern portion of the Hurricane fault and extended northward up the valley of Le Verkin creek, the strata are nearly horizontal. Between that line and the old shore line of the Mesozoic sea west of the Pine Valley mountains the strata are compressed into two synclines and two anticlines which culminate in a great overturned fold at Kanarra. North of Kanarra the continuation of these plications was not studied; toward the south they gradually die out until, fifteen or twenty miles beyond Toquerville, they have greatly broadened and persist only as gentle monoclines dipping toward the east. The most western of these folds is the broad gentle syncline in which lies the lava of the Pine Valley mountains. In the neighborhood of the mountains the dip is everywhere gentle, and the flat bottom of the trough is several miles wide. Toward the southwest this syncline almost vanishes, but the western limb seems to persist as an eastward dipping monocline whose lower limit is now the Grand Wash fault (Marvine, p. 196).

The next fold to the east is a remarkable anticline which runs northeast eighteen miles from Price City south of St. George to Leeds, where it bends more to the north for ten miles, until it is lost under alluvium and lava a short distance north of Bellevue. When what seems to be the same fold reappears at Kanarra it has again bent somewhat to the northeast. Although near St. George this fold is finely exposed as a typical breached anticline, that portion fades into insignificance when compared with the extraordinarily diagrammatic portion near Harrisburg and Leeds. Here erosion has removed all the strata as far as the Shinarump, which at Leeds forms a great rounded nose pitching toward the north and shaped like the decked front of a round-topped canoe (Plate 2 B). As the anticline rises toward the south, the deck of the nose gains a greater elevation, until, halfway from Leeds to Harrisburg, the centre is broken open where it has been undermined by the wearing away of the soft Moencopie shales. A few miles farther south a five minutes' walk from the road southwest of Harrisburg brings one to the top of the Shinarump cliffs on the northwest side of the anticline. Under the observer's feet is the hard Shinarump formation dipping to the northwest at an angle of forty degrees. On its resistant surface erosion proceeds very slowly, and for many miles this edge of the anticline forms a ridge. In front ot the observer a precipitous cliff fifty or sixty feet high bounds abruptly a perfect anticlinal trough, a mile or more wide, a sort of hand specimen or model showing at a glance a diagrammatic type not only of an anticlinal trough, but also of an anticlinal ridge. Under the Shinarump cliffs lie the bright-colored Moencopie shales, red, gray, and brown, the edges of which are truncated like those of the overlying sandstone and conglomerate although at a lesser angle. At the very centre lies a little rounded ridge where erosion has laid bare the harder underlying Aubrey limestone, which rises as an anticlinal core in the midst of an anticlinal trough. Beyond the ridge the naked particolored shales again rise gradually in brilliant bands to a Shinarump cliff exactly like that on which we are standing, except that it faces in the opposite direction and dips to the southeast.

North of Bellevue where the fold disappears under a covering of lava it is still a normal anticline, but where what seems to be the same fold reappears at Kanarra it has been compressed to such an extent that it has been completely overturned and the strata lie in inverted order with a rather steep dip to the northwest. As this fold has been cut at this point by both the old and the new Hurricane faults, only a small portion is now exposed.

The trough lying east of this anticline is unimportant. It dies out completely south of Toquerville, while at Kanarra it is so far compressed that the two limbs touch each other. The most eastern anticline lies close to the line of the Hurricane fault. On the south it flattens out, although the eastern limb persists as an eastward dipping monocline at the base of which is the Hurricane fault (Dutton, *c*, p. 114). In the northern half of the region covered by our map it is a strong arch with a dip of from twenty to forty degrees. The ridge east of Bellevue is formed where it brings up a hard core of Aubrey limestone which has since been bisected longitudinally by the Hurricane fault. On the eastern side of this core all the overlying strata have been stripped off; on the western side where the country has been dropped far down by the fault, the overlying strata are to a great extent preserved.

In a preceding section certain passages from Dutton were quoted, in which he calls attention to the marked resemblance between the conditions of deposition in the Appalachian province of the east during Paleozoic times, and those in the Plateau province of the west during the Mesozoic. Especial attention was called to the close similarity of the eastern Carboniferous which immediately preceded the chief Appalachian folding, and the western Cretaceous which preceded the period of folding that we have been discussing. The similarity seems to be even greater than has been supposed, for in both places at the end of the period of deposition the border region close to the shore of the denuded old land was notably, though doubtless very slowly, elevated. Close to the shore, just where the deposits of the preceding ages had accumulated to the greatest thickness, the uplift was greatest. Here too flexing and folding were induced in lines parallel to the former sea margin, while the strata that lay farther out to sea were almost undisturbed, and now lie essentially horizontal, both in the Allegheny plateau on the one hand and in the plateaus of the Colorado on the other. It seems to be a well-established conclusion that in the Appalachians this folding was due to pressure exerted in a direction tangent to the earth's crust and at right angles to the shore line. This acted in such a way that the upper parts of anticlinal folds appear to be shoved away from the old land, and the plications now stand in unsymmetrical attitudes. In the Plateau province most of the flexing is monoclinal and of far simpler character than in the Appalachians. As these displacements involve but little horizontal compression, it has generally been assumed that they are due to the action of vertical forces by which one block was merely raised above or depressed below another (Gilbert, *b*, p. 86). In the Toquerville area and northward, however, we have a small district which has evidently been subjected to tangential pressure. The folds thus produced are of the true Appalachian type, and at Kanarra are thrust over one another on a small scale, just as is the case in certain parts of the eastern mountains. Both in the East and in the West the direction of movement was such as to incline the tops of the anticlines away from the neighboring old land. South of the Pine Valley mountains these true folds of the Plateau province flatten out into monoclinal flexures. The query arises whether the monoclinal flexing of the Plateau province as a whole may not be a phase of a close folding of the Appalachian type, where for some reason most of the strata were affected but slightly. The manner in which the folds of the Toquerville region are intensified immediately east of the great lava mass of the Pine Valley mountains and bend around parallel to it is certainly remarkable. The mind at once attempts to formulate some causal relation, but that would be going farther than is warranted by our present knowledge.

Gilbert (*a*, p. 62) has suggested that the faults of the Basin Range and Plateau provinces are the superficial expression of a deep-seated structure such as that of the Appalachians. Otherwise expressed, his hypothesis is that far below the surface there was great tangential pressure which forced the lower part of the crust into plications of the Appalachian type. The superficial layers, however, were not so folded, but were raised and broken into blocks, as a sheet of ice may be broken by a wave that passes under it. This hypothesis seems to agree with all the known facts, including the new ones found in the Toquerville region. In Gilbert's discussion he has shown (*a*, p. 59), as has also King (*a*, p. 744), that the Tertiary faults of the Basin Range and Plateau provinces follow the same lines as the plications of an earlier Jurassic upheaval. He has not, however, distinguished between the folding and flexing which took place in the early Tertiary on the one hand, and the periods of faulting which we shall later show to have occurred at the middle and end of that era. If Gilbert's hypothesis is correct, the strata that were deeply buried at the time when the earth's crust was disturbed must have been highly folded, those at moderate depths must have been gently flexed, and those near the surface must have been faulted. None of the deep-seated strata are to-day exposed. The strata in which the Jurassic and early Tertiary plications are now visible at the surface were at the time of folding buried beneath a moderate depth of overlying strata, and usually show gentle folds formed without faulting. Those layers in which the later movements are shown were relatively close to the surface, and are almost always faulted without bending, since they were free to break as soon as they were strained. The line of greatest displacement seems to have shifted eastward from the Basin Range province in Jurassic times to the western margin of the Plateau Province in the early Tertiary, and to the centre of this latter province in the middle Tertiary. In the most recent uplift it has shifted back toward the borderland between the two provinces.

RESULTING TOPOGRAPHY. At the end of the period of folding and flexing, which was probably completed early in the Miocene, there must have been a time of quiet of uncertain duration, the turning-point between the movements which we have been discussing and those of an opposite character which followed. Let us pause long enough to get in mind the condition of the country at this time in so far as we are able to restore them. As we have seen, the region around Toquerville had been thrown into a series of close folds which toward the south fade into eastward dipping monoclines. Farther east there were a number of similar monoclines (Dutton, *c*, pp. 41, 115, 128, 185). On the basis of these facts we can to a certain extent reconstruct the topography of the country, although erosion, the amount of which we cannot measure, must have greatly changed it from the simple forms due merely to the original rock structure. To the west lay the elevated and probably maturely dissected "old land" which is now the Basin Range province. East of this was an extensive area of recently uplifted sediments, a raised and more or less folded and flexed coastal plain. Neglecting for the moment the effects of erosion, the western part of this consisted of a narrow belt of closely folded mountains near Toquerville not far from the old sea margin. The greater part of the coastal plain, however, consisted of a series of broad initial terraces which descended gradually eastward toward the distant sea, and of which the steep portions were formed by the gently dipping monoclines. To what extent the strata had been dissected and removed by erosion we cannot say, nor do we know the course of the streams. If the drainage was consequent, as would in all probability be the case on such an uplifted coastal plain, the main rivers ran eastward, in a direction opposite to that which they now follow.

The First Faulting.

We may now consider the first faulting, whereby these monoclines, which ran north and south, were cut longitudinally by great faults. The plateau region now became a series of blocks, separated by faults, which in each case involved an uplift on the east and a downthrow on the west. Dutton (*c*, pp. 21, 41, 113), Gilbert (*a*, p. 54), and Marvin (p. 196), all speak of the fact that all the great faults of the plateau region, which at present determine the leading features of the topography, follow the lines of older monoclinal flexures that dip east. "It is certainly remarkable that the distinct flexures of the Grand Canyon district dip eastward so generally, while the faults have their throw to the west with almost equal regularity. In all cases where this obtains, the later movement by faulting was of greater measure than the earlier movement by flexing. It is further noteworthy that the unfaulted or least faulted flexures . . . lie to the east, while the distinctly faulted flexures lie to the west" (Davis, *b*, p. 149).

The fact that the displacement by faulting is exactly opposite in its vertical effect to the earlier movement by flexing seems to indicate that the two movements represent two distinct periods of uplift, — an earlier one which, in the Toquerville district at least, witnessed tangential pressure of the Appalachian sort, and a later one in which there was only vertical uplift.

The fault with which we are chiefly concerned — the old Hurricane fault — may be traced from the Colorado river northward one hundred miles to Kanarra. It probably extends far beyond these limits; but that is a matter for future study. At Coal spring, twenty miles north of the Colorado river, we first saw the old fault; next we visited it at a point on the Hurricane, fifteen miles north of Coal spring; and again, after an interval of twenty-five miles, near Antelope wash. From near Fort Pierce, about on the Utah boundary, we followed it to Kanarra, making this portion of the fault line our special study. Along this part, the Utah part, of the Hurricane, the evidence of the old fault is associated in rather a confusing way with the more apparent evidence of the second faulting, which is much more recent, and gave rise to the present Hurricane scarp. South of the Arizona line, however, the Hurricane fault, so far as we have observed it in the field, consists chiefly of the old fault, with the newer displacement greatly diminished.

Near Coal spring, for instance, we found no signs of a recent fault; but beneath a protecting basalt cap that forms a promontory in the Hurricane ledge there was displayed a portion of the old fault line. The lava rests on a nearly level surface that horizontally truncates the old fault. Beneath the black cap the red Moencopie shales on the downthrown western side of the fault butt against the gray Aubrey limestone on the east of it.

The amount of dislocation shown by this relation of strata is about six hundred feet, and is much less than the throw of the old Hurricane fault farther north. That this is not a recent fault is demonstrated by the surface on which the lava lies. This, as will be seen later, furnishes evidence of a long period of erosion that reduced this part of the country nearly to base-level before the more recent faulting took place.

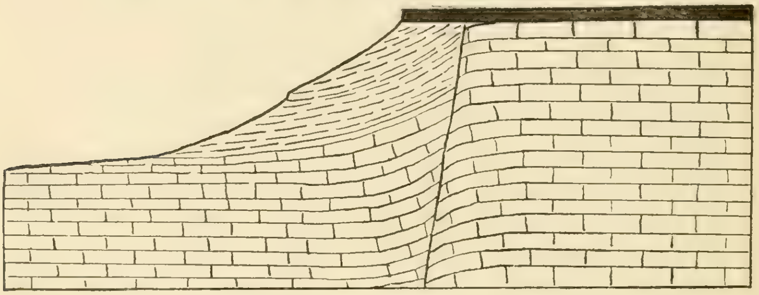


FIGURE 4.
The Hurricane fault at Coal spring.

Hardly less apparent than the Coal spring exposure, and certainly more striking because of its greater complexity, is the fine cross-section on the Hurricane just southwest of Gould's ranch. Here a section about a mile long contains a record of the ancient faulting, the succeeding long period of erosion, the basalt flows, the second or modern faulting, and recent erosion (see Plate **7**, section G–H). The observer, from one of the little lava mesas that overlook the Hurricane ledge, sees directly at his feet the red and gray Moencopie shales sloping steeply down to the top of the cliff proper, which consists of hard Aubrey limestone, and drops down abruptly one thousand feet. At the base of the Aubrey cliff, or fourteen hundred feet below the observer, lies black lava that matches the basalt cap on which he stands. He recognizes that in this discordance of altitude of the two parts of the lava sheet he has a measure of the recent fault, which formed the steep scarp. But his eye discovers more than this. Down beneath the lava that lies beyond the cliff he sees the brick-red Kanab sandstone. We can quickly reconstruct the section before him, as it must have looked just after the lava flow and just before the recent faulting, by imagining the ground on which he stands to sink fourteen hundred feet until the lava cap of the mesa lies alongside the lava west of the fault line. On the east, under the lava, there is lower Moencopie shale; on the west, under the lava, is Kanab sandstone. The flow of basalt covered an ancient fault. The lava must have flowed across a base levelled fault line where a displacement of about fifteen hundred feet had brought Kanab against Moencopie. The lava itself was then faulted, forming the present scarp.

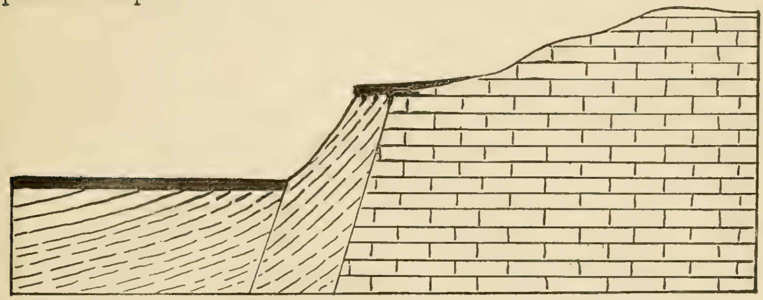


FIGURE 5.
The Hurricane fault at Virgin canyon.

Near where the canyon of the Virgin river cuts through the Hurricane ledge, there is a condition of things somewhat similar to that just described (Fig. 5). The steeper part of the escarpment, as before, is the product of the recent fault, which has here a throw of only three hundred feet. Up the canyon, just east of the scarp, a part, at least, of the old fault is shown by an exposure in the canyon wall. Here again the old fault is preserved under a basalt sheet. On the lifted eastern side of the fault, Aubrey limestone lies nearly horizontal; against it on the downthrown side are Moencopie shales that dip steeply towards the west (Plate 3 B). On either side of the river, where it crosses the old fault line, warm sulphur springs issue from the foot of the canyon walls. Within half a mile of the fault, on its downthrown western side, a white sandstone, probably Colob, that appears under the lava sheet, shows a very steep dip towards the west, although a little farther west in a second exposure this has greatly decreased. This sudden change of dip suggests that under the lava between the two exposures there may be another old fault in addition to the one seen at the sulphur springs. Of this, however, there is no proof; and the steepness of the dip alone may be sufficient to bring the Colob sandstone to its present low level on the downthrown side. The displacement as measured along the fault in the canyon is relatively small, bringing Aubrey against Moencopie. The entire displacement, however, including that due to flexing, amounts to thirty-five hundred feet, the vertical measure of the strata between the Aubrey and Colob formations.

From Virgin canyon northward as far as Toquer hill, the old fault seems to follow the Hurricane escarpment; for just south of Toquer hill, a few hundred yards west of the Aubrey wall, there are several exposures of red Kanab and white Colob sandstone that dip steeply west and are in places capped by gravel and lava. They are like the exposures of downthrown strata in the Virgin canyon, and seem to occupy a corresponding position on the same side of the old fault.

From Toquer hill northward to Kanarra, the old fault is covered, for a distance of twenty-five miles, under a belt of basalt and alluvium that stretches along the base of Bellevue ridge and of the escarpment of the Colob plateau. That the fault is merely concealed and does not die out is indicated by the fact that the displacement between the strata west of the lava belt and those of Bellevue ridge east of it is much more than that of the lava which is displaced by the new fault. Moreover at Kanarra an old fault is clearly distinguishable in the strata at the base of the Colob plateau. It crosses the prominent escarpment of the new fault at a very slight angle. To the northeast it cuts the overturned strata of the closest of the folds that have been described above, and seems to have displaced them many thousands of feet. At the line of the new fault it is cut off sharply as if by a knife. It seems highly probable that from Toquerville to Kanarra the old fault increases rather than decreases.

The Inter-Fault Cycle of Erosion.

After the completion of the first faulting the Plateau province entered upon a long cycle of quiet erosion which was brought to an end by a second period of faulting. During this inter-fault cycle the work of erosion begun while the first faulting was in progress was carried forward to such an extent that the topography assumed a thoroughly mature character or even reached old age. The original topography due to faulting and folding was so far effaced that the valleys of the main streams were reduced nearly to base-level, forming the Mohavé peneplain. In the more remote regions there were low rounded mountains with well-graded slopes, and the Pine Valley mountains had almost as great relief as at present. Differences in hardness of strata produced practically no effect in the most completely base-levelled regions. Even in less eroded places erosion had gone so far that a fault scarp several thousand feet high had been worn away and even reversed, so that the hard strata of the downthrown side stood higher than the softer ones of the uplifted side. Near the end of the period there was considerable aggradation in many valleys, and numerous volcanoes poured out large sheets of basaltic lava.

The evidence of this long inter-fault cycle is found in facts of five classes which will be more fully discussed in the succeeding paragraphs. (1) The much greater northward recession of transverse cliffs on the upheaved than on the downthrown side of the faults demands a long lapse of time since the first faulting. (2) Many maturely dissected or even base-levelled surfaces belonging to the ancient topography have been buried by lava flows, and are now exposed in cross-section in the walls of young canyons or in the scarps of recent faults. (3) Portions of the lofty plateaus lying at a distance from their borders exhibit an upland surface of subdued graded slopes and broad valleys utterly different from the precipitous youthful slopes of the peripheral regions. This surface seems to be a part of the mature topography of the previous, or inter-fault cycle that has not yet been effected by the renewed erosion of the present post-fault, or canyon cycle. (4) At Kanarra the old Hurricane fault is crossed by the new one running almost parallel to it. The contrast between the mature topography of the one and the young topography of the other indicates a great difference in age. (5) During the latter part of the inter-fault cycle many valleys where erosion is now active were areas of deposition. The surface on which these deposits lie shows broad flat valleys the floors of which truncate highly inclined strata without reference to their attitude or texture. Corresponding to the valley floors are gently sloping grade plains, the sides of the ancient valleys, which lie at a higher level and are now being undercut. These two types of surface seem to indicate a previous topography far more mature than the present.

(1) Recession of Cliffs. In their present position the strata of the central and western part of the Plateau province have a gentle but very persistent dip to the north. It is often locally complicated by dips to the east due to faulting or by the eastward dip of the old monoclines. Its persistence and general uniformity of direction, however, find expression in the long lines of south-facing cliffs which cross the country at right angles to the dip. These are due to the alternation of hard and soft strata. As the later are continually worn away, the harder beds that overlie them are left without support and fall as talus, causing the cliffs to retreat continually northward down the dip. The hard talus that falls from the cliffs gradually piles up at their base and checks their rate of retreat. The amount of this checking depends on the rapidity with which material is carried away from the foot of the cliffs, and this in turn depends on elevation above base-level. Hence, where faults cut the cliffs at right angles, as the north and south faults cut the cliffs in the Plateau province, the cliffs on the heaved side, being at a greater elevation, are more fully exposed to the effects of erosion and retreat faster than those on the low-lying downthrown side. Powell (*b*, p. 191), Gilbert (*a*, p. 51), and Dutton (*c*, p. 200) all recognize this, but, as Davis has pointed out (*b*, p. 144), "they do not explicitly connect the amount of recession with the date of faulting." Moreover, as the same writer has shown, the present interval between the corresponding cliffs on the two sides of a fault represents not merely the amount of recession since the faulting occurred, but the excess of the retreat on the heaved side over that on the thrown side.

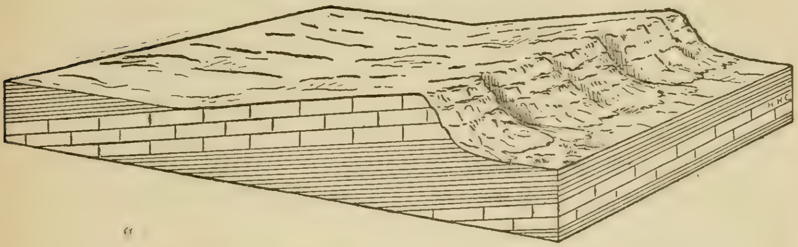
Near Toquerville the cliffs formed by the Kanab sandstone are fifteen miles farther north on the eastern or uplifted side of the Hurricane fault than on the western side. The first faulting must have taken place so long ago that the upper cliffs have had time to retreat fifteen miles farther than their counterparts on the thrown block. On the other hand, formations which are separated only by the later faulting match very closely on the two sides of the line of displacement, indicating that this took place quite recently. Between the two periods of faulting there must have intervened a long inter-fault cycle of erosion.

(2) Old Surfaces covered by Lava. Further evidence of the length of this inter-fault cycle is found in the old surfaces, portions of the ancient topography, preserved under recent lava flows, and now exposed in cross-section where the lava is cut by canyons or by the recent fault. Several of these have been already mentioned. It will be recalled that at Coal spring and at the mouth of the Virgin canyon lava

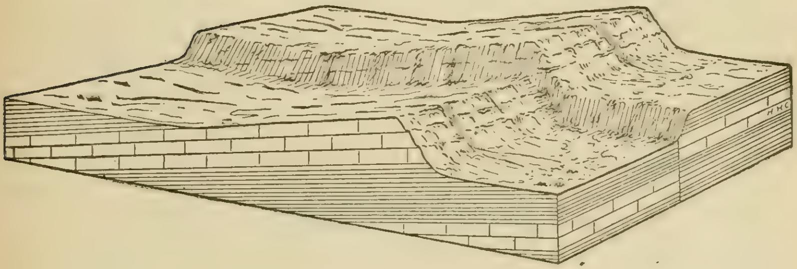
FIGURE 6.

Block Diagrams illustrating the Differential Recession of Cliffs on the Two Sides of a Fault.

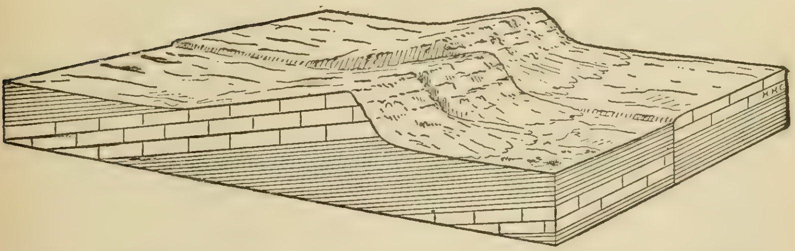
(From Journal of Geology.)



Unfaulted block showing a continuous line of cliffs.



The same block cut by a north-south fault.



The same block after erosion has almost obliterated the fault scarp. The cliffs on the eastern or upthrown side of the fault have retreated much farther than those on the downthrown side.

flows across the old fault, on one side of which is hard Aubrey limestone while on the other is soft Moencopie shale. In other words, when the lava was poured out the country was so far worn down toward base-level that the difference in the two kinds of strata was of comparatively little importance. At present, where these two formations lie side by side above base-level and are exposed to erosion, the shale is very rapidly worn away, leaving the limestone as an escarpment. At the time of the lava flows the junction of the two seems to have been so close to base-level that the hard and soft strata on the two sides of the fault were worn down to a level or only gently sloping surface, and lava from the downthrown side flowed across the fault line. This does not mean that the entire region was reduced to the lowest possible level, for near the Virgin river the lava after crossing the fault was soon checked by an escarpment of limestone rising two or three hundred feet with a fairly strong slope.

At Sugar Loaf, the third of the localities already mentioned, and on the Shivwits plateau there is evidence of a local base-levelling of a more pronounced type. Here the surface at the time of the lava flows previous to the recent faulting consisted of Moencopie shales. These are very soft rocks which, under present conditions of high altitude and consequently of active erosion, never form a level surface of any considerable extent. As soon as the protecting cap of Shinarump sandstone and conglomerate is removed, the shales are dissected into a regular bad-land topography and erelong melt away entirely. Yet under the lava flows there is an extensive flat surface of just such shales, which does not even correspond with the bedding planes of the rock, but bevels the strata at a slight angle, and so cannot be due to any particular layer of unusual hardness. Such a surface can only be produced close to base-level. As it is best exemplified in the Shivwits plateau which lies in the centre of Mohave county, Arizona, we shall hereafter refer to it as the Mohave peneplain.

Farther north between Toquerville, and Dry canyon, a lava flow some fifteen miles long and from two to three miles wide lies partly in the valley at the western base of the Bellevue ridge and partly high up on the top of the ridge. The two portions have been broken apart and displaced from one thousand to fifteen hundred feet by the recent Hurricane fault. The lava seems to have come from a group of craters near the northern end of the flow, and located in part on the upheaved and in part on the downthrown side of the fault. The basalt from these flowed southward down the Bellevue valley. On the west it was checked by the foothills of the Pine Valley mountains, on the east it was limited by the upstanding Carboniferous limestone of the Bellevue ridge, over which as a rule it could not flow. In certain places, however, the lime stone pitches down so as to pass below the level occupied by the peneplain of that time. Wherever this is the case, the basalt spread out to the eastward and covered the bevelled edges of the softer strata that overlie the Carboniferous. The most marked example of this is two or three miles south of Dry canyon at an elevation of sixty-three hundred feet just east of the Hurricane fault (Fig. 7). Here the level surface on which lies the uplifted lava is composed of Moencopie shale, Shinarump conglomerate, Painted Desert shale and sandstone, and Kanab sandstone, all dipping strongly to the east. Where the same strata are exposed to erosion the hard Shinarump and Kanab form strong cuesta-like ridges separated by valleys excavated in the soft Moencopie and Painted Desert (Fig. 3). Only under conditions approaching closely to base-levelling would it be possible for a level surface such as that beneath the lava to truncate smoothly strata of such varying hardness.

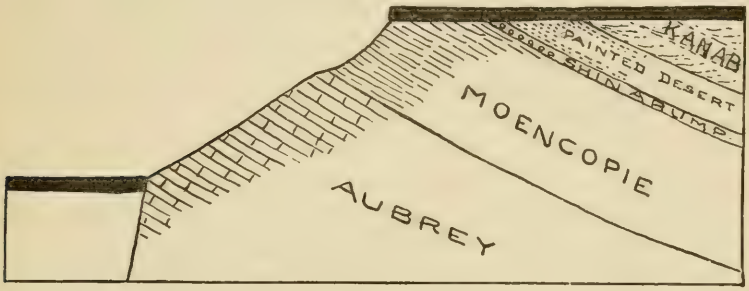


FIGURE 7.
Bellevue ridge four miles south of Dry canyon.

(3) PORTIONS OF THE ANCIENT SURFACE NOT COVERED BY LAVA. At the mouth of the Virgin canyon, as we have seen, lava seems to have flowed across the fault line from the downthrown side and to have been soon checked by an escarpment of limestone rising nearly four hundred feet. A reference to the illustration (Plate **3** B) shows in the middle of the picture a precipitous slope, the scarp of the modern Hurricane fault. This rises three or four hundred feet to a terrace a few hundred feet wide formed by the uplifted eastern portion of one of the lava flows. Behind this the ascent consists of rounded maturely dissected slopes of quite a different character from the youthful cliffs below

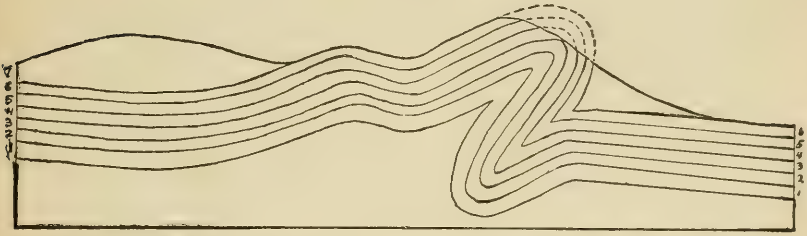
them and from any of the cliffs that are due to recent faulting. These slopes have been renewed and steepened by recent erosion, but nevertheless they are continuous with the surface under the lava and seem to be the product of the same period of erosion. If our interpretation is correct, the mature topography at the top of the escarpment is a battered remnant of that which prevailed before the plateau region was uplifted at the time of the last great faulting. West of the fault where the main body of the lava sheet now lies, soft sandstones and shales had allowed the reduction of the surface nearly to base-level; east of the fault relatively hard limestone produced a gentle escarpment rising to a plateau three or four hundred feet higher than the adjacent lowland, a Monadnock of Carboniferous strata in the Mohave peneplain.

A more perfectly preserved example of the ancient topography is displayed in the lofty plateau of Colob, a few miles beyond the northeastern corner of the area shown on our map. This forms a portion of the upheaved block east of the Hurricane fault, and lies at an elevation of from eight thousand to ten thousand feet. On the west it is bounded by a great escarpment, due in part to the old fault and in part to the new one, as will be explained later. To the south it is limited by the imposing Vermilion cliffs, nearly two thousand feet high, which here reach their greatest development. To the north and east it stretches away indefinitely, until it merges into other portions of Dutton's High plateaus, of which it may be considered a fair sample. Around the edges of "Colob," as it is locally called, the revived activity of erosion consequent on the last faulting has caused most energetic dissection, and steep cliffs, naked ledges, and profound canyons are the rule. In the centre of the plateau, however, the ancient pre-faulting topography is still preserved in broad vistas of gently sloping hills and dales, the finest of summer pasture for sheep and cattle. Sometimes for miles scarcely an outcrop appears. The relief, to be sure, is considerable, amounting to fully two thousand feet, and in certain places the hills might well be called mountains if that term could be correctly applied to an elevation having a distinctly non-mountainous structure of nearly horizontal strata. The maturity of the topography and its contrast to the youthful character of the peripheral regions are so marked that we seem forced to believe that it is the product, not of the present canyon cycle, but of the previous inter-fault cycle.

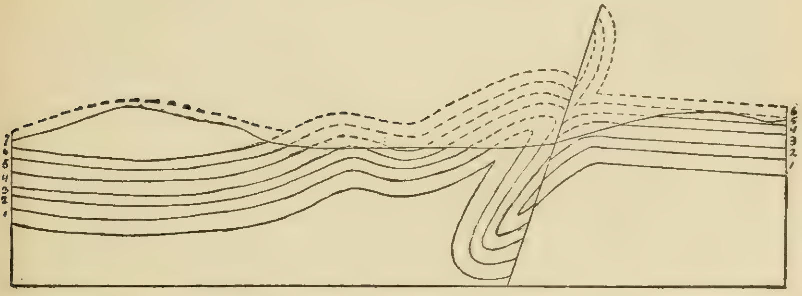
(4) THE NEW AND THE OLD FAULTS AT KANARRA. The escarpment which bounds the Colob plateau on the west shows the old fault and the new exposed under conditions where it is easy to compare their

FIGURE 8.

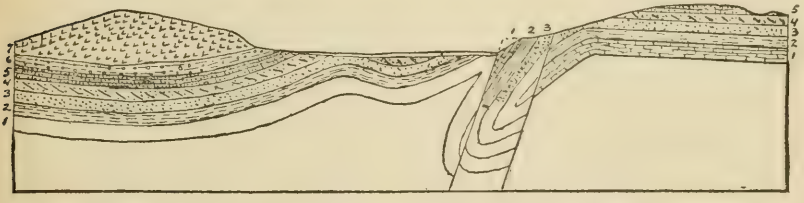
Cross-section of the Hurricane Fault near Kanarra, looking North.
(From Journal of Geology.)



Ideal section after the early folding.



Restoration of section at the end of the inter-fault cycle of erosion. The dotted lines represent the section at the beginning of the inter-fault cycle.



Section representing present conditions. 1, Aubrey limestone; 2, Moencopie shales; 3, Painted Desert shales and Kanab sandstone; 4, Colob sandstone; 5, Cretaceous; 6, Tertiary; 7, Andesite.

topographic effect and hence to estimate their relative age. To the east at the top of the escarpment is the maturely dissected upland, to the west at the base of the slope is a broad intermont basin floored with waste brought down from the uplifted region around it.[1] The escarpment itself shows at the top the mature slopes of the undisturbed ancient surface; farther down these grow more rugged and ledgy under the influence of renewed erosion, and at the base is the straight step scarp of the modern fault. South of Kanarra these simple features are varied only by the texture of the rocks and the size of the streams. It is near this little Mormon village, however, that the old fault reappears after being concealed for many miles under alluvium and basalt. It will be remembered that the new fault here crosses the old one at an acute angle shearing off the western and southern portion. To the north both faults can be easily traced. The long slender wedge between them is composed of strata which were overturned at the time of the early folding and now lie in inverted order with a strong westward dip (see Fig. 8). Dutton speaks of the overturned fold and complicated fault at Kanarra as showing an exceptional movement (*a*, p. 29). Along the line of the old fault between these reversed strata on the west and the very slightly inclined normal strata on the east the slope of the escarpment everywhere diminishes, forming a slight terrace or even a little depression contouring along the slope. This is due to the fact that on both sides of the fault lie soft strata, while above them is the great mass of the plateau on the one hand and the cuesta-like ridges of the hard Aubrey limestone and Shinarump conglomerate on the other. Thus it happens that the old fault which geologically amounts to many thousand feet, has been entirely effaced geographically and is even replaced by a valley. More than this, the valley was not only worn out along the ancient fault line before the period of the second faulting, but was also filled in part with gravel, and on the gravel was poured out a lava flood. That the lava was poured out before the last faulting is indicated by the fact that it lies horizontally on what is now a hillside, but was then a valley floor. Moreover the erosion consequent on the uplift at the time of the later faulting seems to be the only competent cause for the dissection of the lava-covered gravel into flat-topped buttes, where the loosely cemented pebbles are protected from erosion by a sheet of basalt. The relation of the two faults at Kanarra indicates that they are of different age. The topography seems to show that one is ancient, the other modern, and that between the two there was a long period of erosion.

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[1] This plain lies at an elevation of about six thousand feet, and forms part of the divide between the interior basin and the Colorado river. It is so flat that several streams flowing out of the mountains are sometimes deflected northward to Sevier lake and sometimes southward to the Pacific ocean.

(5) EVIDENCE OF PROLONGED EROSION IN THE DOWNTHROWN BLOCK WEST OF THE HURRICANE FAULT. In the preceding paragraphs most of the evidence on which we have based our conclusions as to the amount of erosion during the inter-fault cycle has been drawn from the upheaved block east of the fault. If our theory is correct, the downthrown, or St. George, block on the other side ought to preserve much more perfectly the topography of the close of the inter-fault cycle, provided that this western block, too, has not since suffered elevation or depression. The slopes ought to be gentle and well graded; the valleys ought to be broad and waste-filled, and should truncate the underlying formations without reference to the attitude of the strata; and lava sheets ought to be almost undisturbed by the erosion which is rapidly dissecting into buttes the similar formations of the block upheaved by the second faulting. If, however, the block was depressed at the time of the last faulting, although we should expect to find these same topographic features, some of them would be drowned under new deposits of waste. If, on the other hand, the western block was somewhat elevated at the time of the faulting, we should look for a combination of the mature topography of the inter-fault cycle and the youthful topography of the present canyon cycle. The relative amounts of the two would depend largely on the amount of uplift, the lapse of time, and the texture of the strata. As a matter of fact, it is just such a combination of mature and young topography that we find all along the eastern border of the Basin Range province at the foot of the Hurricane and Grand Wash faults.

For example, where the Virgin river, after crossing the Hurricane fault, emerges from its limestone canyon, it enters a region of which the surface is now basaltic lava. In this the river has cut a steep-sided trench a hundred feet deep. In the sides of this young canyon and to a greater extent in the sides of the similar young canyons of Ash and LeVerkin creeks, which here join it from the north, an old surface of sandstone is disclosed. The maturity or even old age of this surface is borne witness to by its extent as indicated by the breadth of the deposits of gravel and beds of cobbles which lie upon it and are in turn covered and preserved by lava. Still further evidence of its age is found in the fact that it truncates highly inclined strata without paying any attention to their attitude or relative resistance. In this it is like the rest of the Mohave peneplain, of which it forms the northern part.

West of Leeds and Harrisburg, at the southwestern base of the Pine Valley mountains, we have more marked remnants of the ancient topography in the form of long, gently sloping grade plains which are now mere strips stretching forward from the edge of the mountains. As one looks westward from Leeds, most of the view consists of naked hills with steep rocky sides of red, white, and brown sandstone. The harder layers stand up as cuesta-like ridges across the spurs which run out from the mountains toward which the strata dip; the softer ones form depressions separating these lines of elongated knobs, which, if united, would form cuestas. Both alike are almost bare of soil, and support scarcely any vegetation except sagebrush and cactus and a little desert grass. Here and there, however, almost parallel to the present valley floors although several hundred feet above them, run long but broken lines of green, sloping gently from the mountains toward the river. They seem to be remnants of the former mature topography, not yet consumed by the revived erosion of the canyon cycle. Their verdure is in part merely apparent, because they are level and hence are seen foreshortened, while in part it is real because of the fact that they are well graded and hence have a depth of soil sufficient to support a growth of juniper trees.

Other examples of a similar kind are found near St. George and along the South Fork of Ash creek near Bellevue. In the former place, which will be described at some length below, the erosion of the present cycle has gone so far that but little remains of the old topography except those portions that are buried under lava flows. These form mesas, and along their borders are exposed most excellent sections of the ancient topography, showing conclusively its mature character. The South Fork locality, on the other hand, lies near the headwaters of the stream, and in a place where lava flows a little farther down Ash creek have prevented deep erosion. Accordingly here the features of the former cycle are well preserved. They take the form of broad well-graded slopes lying between sharply incised canyons of no great depth which represent the erosion of the present cycle.

Turning now to some places at a greater distance from the Hurricane fault, but still belonging to the downthrown St. George block west of the displacement, we find that near Black Rock, forty-five miles southwest of Toquerville, the broad flat notch at the divide between the Grand wash and the Virgin displays for the most part a mature type of topography, even where there is an ascent of a thousand feet to the Shivwits plateau on the east and to the Virgin mountains on the west. Twenty-five miles down the Grand wash the main features of the topography are still mature so far as the St. George block is concerned. Here and there, however, are evident indications of renewal, such as a shallow canyon cut through a lava flow, or the shallow valleys which all the streams have cut in the heavy gravel deposits which fill the bottom of the wash and therefore belong to a time anterior to the last great faulting. Thirty miles farther southwest — that is, about one hundred miles southwest of Toquerville — at Scanlon's, or, as it is now called, Gregg's ferry, fifteen miles below the mouth of the Grand canyon, the same feature is seen. The Colorado river has intrenched itself to a depth of about two hundred feet in heavy gravels which at an earlier time must have filled its broad valley to a considerable depth. The extensive valley floors, grade plains, and the other forms of mature topography west of the Hurricane all seem to indicate that at the end of the inter-fault cycle the topography of the St. George block was of the same type as that which we have already described from smaller samples preserved in the uplifted block east of the Hurricane. In both blocks there has been a renewal of erosion, although it is much more marked in the eastern block. The connection between these renewals will be considered later.

Summary. All the lines of evidence which we have been pursuing lead to the same conclusion. The unequal recession of cliffs on the two sides of the Hurricane fault; the bits of ancient surface preserved under lava flows; the mature topography of the Colob plateau; the contrast between the old and new faults at Kanarra, and the grade plains, mature topography, and broad surfaces covered with gravels west of the Hurricane — all point to a long period of quiet erosion between the first and second faultings. At the end of this inter-fault cycle of erosion the whole country was physiographically mature or even old. Certain regions of soft strata, chiefly near the Colorado river, had been reduced very nearly to base-level forming the Mohave peneplain.

Attitude of the Land, and Topography at the End of the Inter-Fault Cycle.

In our study of the borderland between the Plateau and Basin Range provinces we have already found two critical points, and now have come to a third. The first was at the end of the long cycle of deposition just before the strata were upheaved, flexed, and folded; the second was at the end of the time of quiet, when flexing had ceased and the earlier faulting had not yet begun; the third is at the end of the inter-fault cycle of erosion, just before the beginning of the last great faulting.

The exigencies of language and the necessity of brevity often oblige us to speak of periods of faulting and folding as though they were distinct from those of erosion. According to the old cataclysmic idea, this was indeed the case. We may illustrate this graphically by a diagram in which the course of time is represented by horizontal distance, while the relation of any given stratum to sea-level is represented by vertical distance. The cataclysmic theory supposed that periods of uplift or other tectonic movement were so sudden and paroxysmal that in such a diagram (Fig. 9) they might fairly be represented as vertical lines, since the time element involved was thought to be negligible. A similar diagram representing the opposite or uniformitarian view shows absolutely no vertical lines, and relatively few that are perfectly horizontal. Changes were supposed to take place so slowly that there was comparatively little chance for absolute rest, and none whatever for sudden transformations. The modern or eclectic view is a combination of these two. It supposes the existence of distinct periods of essential rest separated by longer or shorter periods of unrest, during which there

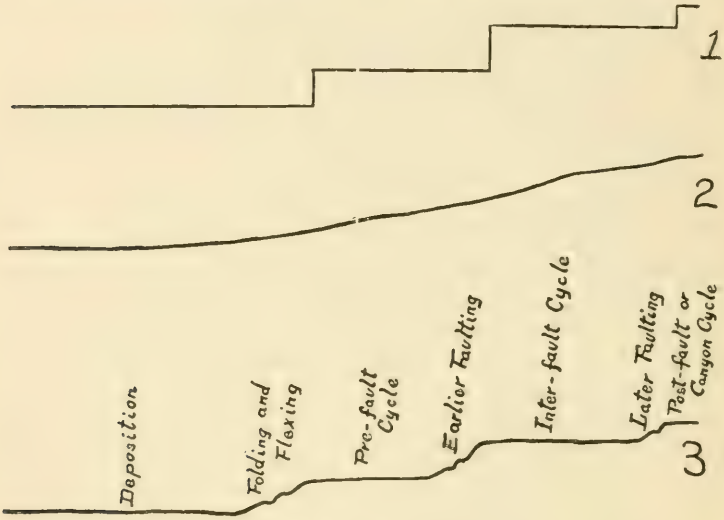

FIGURE 9.

Diagrammatic scheme of cycles. 1, Pure cataclysmic view; 2, Pure uniformitarian view; 3, Eclectic view.

is upheaval or depression accompanied by flexing, folding, or faulting. These movements begin and end slowly. They are of considerable duration, and are varied by minor times of very rapid change or of almost complete quiet. Erosion proceeds as before, and is active or inactive in the normal fashion in proportion to the elevation of the country on which it works. As applied to the Plateau province, this view of earth movements is graphically illustrated in the last of the three diagrams in Figure 9. In this it is seen that since the end of the long Mesozoic period of deposition there have been three periods of uplift separated by longer periods of quiet. The former, however, were not continuous but were broken up into many episodes, when short periods of rest followed those of violent movement. Erosion continued unchecked at all times, but was divided into three distinct cycles.

The initial stage of what Davis (*c*) has called a geographical cycle is a period of uplift during which erosion is revived and a region becomes young. The remaining stages of the cycle are carried to completion during the succeeding period of comparative rest. An ideal cycle involves not only the initial uplift whereby the country becomes young, but also a far longer time of little movement during which the relief passes through all the stages of maturity and is finally reduced to the featureless peneplain of extreme old age. In another sense, however, the term cycle implies not the whole, but only a part of this long lapse of time. It is any period of erosion which begins in a movement of uplift and is brought to a close by another tectonic movement either of elevation whereby erosion is revived and a new cycle introduced, or of depression whereby erosion is brought to a standstill by the encroachment of the sea. Such interruptions may occur at any time, even in early youth, but the interval from the beginning of one to the beginning of another is still a cycle. The word "cycle" is used in a sense analogous to that of the word "life," and like it may be used in two distinct but complementary ways. Life in one signification is the complete existence of a normal organism during which it passes from infancy through youth, maturity, and old age to death. The life of man in this sense is seventy years. In another sense life is merely the actual period of existence of a specific organism. An animal whose life in the first sense of the word is fifty years, may die the day that it is born, but nevertheless we say that it has finished its life. A cycle in the first sense is ideal and can never be realized, since infinite time would be required to reduce any land mass to the condition analogous to death, that is, to a plain at absolute base-level. In the second sense any region that is subjected to erosion during a definite period, no matter how short, passes through a cycle and can be described in terms of age and development.

Referring again to the diagram, it will be seen that the three periods of erosion that are discussed in this paper — the pre-fault, inter-fault, and post-fault or canyon cycles — are not rigidly limited by hard and fast boundaries. They shade off into one another, and no one can say exactly where one ends and the other begins. Nor can we say that in any two of them erosion has proceeded to exactly the same extent, for the two cycles that have come to an end were interrupted long before they had been carried anywhere near ideal completion, and the present cycle is still very little advanced. In certain places, to be sure, the inter-fault cycle had proceeded so far that the country was in the final stage of development, old age, but elsewhere either because the strata were harder or were less exposed to attack, the same length of time had only been sufficient to reduce it to the middle of maturity. Yet both these types fit perfectly into the cycle scheme of treatment. So, too, if to-day in its extremely youthful condition the plateau region should sink below sea-level, the canyon cycle would still have all the attributes of a true cycle in the second of the senses defined above.

One further feature illustrated by the diagram deserves attention. A period of faulting, like a cycle of erosion, seems to involve a definite series of systematic changes. From a feeble, perhaps imperceptible beginning, it, theoretically at least, passes through a period of increasing strength until the rate of dislocation reaches a maximum. It then becomes gradually weaker and gradually dies out. If it would not lead to confusion, these stages, as well as those of the cycle, might fitly be termed youth, maturity, and old age; but it must be clearly borne in mind that when faulting has attained old age or death, the cycle of erosion that it introduced may still be in early youth or at most can only be in maturity.

In considering any period of uplift it is necessary to take into account not only the processes and changes which are represented by the vertical component of the diagram (Fig. 9), but also of those features which are represented by horizontal space. Accordingly a complete treatment of a displacement such as that of the Hurricane fault involves three main heads. (1) The first is the condition of the country before the faulting. Were the strata horizontal or plicated? Was the surface above or below sea-level? If it was above sea-level, had it been subjected to little or much erosion? and are any traces of the pre-faulting topography preserved from which we can reconstruct the whole? (2) The second consideration is the displacement itself, — its measure and plan, horizontally and vertically, and its date. This part of the subject is the only portion that is commonly treated systematically and fully. It represents the vertical component of the diagrams of Fig. 9. It is more definite and more easily worked out than the other divisions of the subject, and can be more easily stated, but it is of no greater importance. The case is analogous to that of mountains where the ridges and peaks, the culminating portions, are easy to apprehend and have been mapped and described again and again, while the slopes in spite of their varied form and great extent are passed over without minute observation and are almost never well described. (3) The third division involved in a treatment of faults is the changes that have taken place since the displacement. It is usually tacitly assumed that a discussion of these is necessary, but the subject is commonly dismissed in a few sentences, as though it were something that every one could picture for himself. Yet such is by no means the case. Definite, careful statement is as essential here as it is in the description of the fault itself.

In our account of the first folding and of the earlier Hurricane fault we have briefly considered these three aspects. In what follows we shall treat the later faulting in the same way, but with more detail. The topographic condition of the country has already been considered under the head of the inter-fault cycle of erosion. It is further necessary to restore the whole region to its former attitude with respect to sea-level, including the relatively downthrown as well as the uplifted portions. We shall begin with the most elevated block, which was probably also the one that last suffered movement, and shall restore the different parts to their places in an order inverse to that in which they were displaced. The first step in this process is to lower the upheaved block east of the Hurricane fault until its lava sheets match those of the downthrown block to the west. This, however is not enough, for, as we shall see later, a very considerable part of the uplift that introduced the canyon cycle took place along the Grand Wash fault. If the region disturbed by this latter displacement is restored in the same manner to its former position, we find that the southern end of the Shivwits plateau is thereby lowered from its present elevation of six thousand feet to only one hundred or fifteen hundred feet. At the northern end of the Grand Wash fault, however, in the valley of the Virgin, the Shivwits plateau, of which the lowest points are now at an elevation of from twenty-five hundred to three thousand feet, is not depressed at all by restoration, while the northern part of the Uinkaret plateau just to the east of the Hurricane is depressed but three hundred feet at the least and fifteen hundred at the most.

Even yet, however, we have not restored the country to as low a level as the facts seem to demand. As we have seen in a preceding section (p. 235), the valley of the Virgin river southwest of Toquerville shows signs of a renewal of erosion, which was probably associated with the disturbances attendant on the recent faulting. The only satisfactory explanation of this seems to be that the western block was upheaved in sympathy with the eastern block, but to a much less extent. Along the Colorado river and Grand wash there are similar indications that the western block was uplifted somewhat, although perhaps less than at Toquerville. For the sake of stating the problem in a quantitative form, let us assume that the farther depression required by the renewed erosion of the western block, in order to restore the region to the attitude which it held at the end of the inter-fault cycle, amounts to five hundred feet along the Colorado river, and one thousand feet near Toquerville. These figures are only approximations, and can be doubled or halved without affecting the verity of our presentation. At Toquerville, then, according to this hypothesis, the northern end of the Shivwits plateau stood at an elevation of from fifteen hundred to two thousand feet. To the southward it descended gently, until at the Colorado river the elevation of the Mohave peneplain was only five hundred, or at most one thousand feet. The strata, which now dip gently to the north, must then have dipped a little to the south, and near the Virgin river there must have been a faint anticlinal arch, with an east and west axis. The Uinkaret, Kanab, and Kaibab plateaus, to the east, must have stood very low also, since there is no evidence of any marked modern break between them and the Shivwits plateau, and since the Grand canyon has been cut in them to a depth as great as in the Shivwits, during what appears to be exactly the same length of time. To the northwest, however, the Colob plateau, and probably the rest of the High Plateaus seem, as measured by the amount of faulting, to have stood at an elevation of about six or seven thousand feet, only three thousand feet lower than at present, but it may be that these figures will require modification. The topography of the plateaus as seen in Colob, and in those described by Dutton, is more subdued and more mature than would be expected in a region standing at so great an elevation, within a few miles of a lowland four thousand feet nearer to sea-level. It is possible that a further study of this comparatively little known region will show that the amount of uplift at the time of the last faulting was rather more than three thousand feet, stated above. Accordingly in the ideal (Fig. 10), we have drawn the pre-faulting surface of Colob four hundred feet below the present level. The Pine Valley mountains, on the other hand, certainly stood at a height of seven or eight thousand feet, and then, even more than now, dominated the landscape for scores of miles on every side.

If the steps of our reasoning thus far have been correct, the master stream of the region, the Colorado, must at this time have been a strong but thoroughly graded river, with a descent of from one to two feet per mile. Such a stream would probably have ceased to deepen its channel, because the heavy load which it received from the highlands would be deposited in the lowlands, and would act as a cloak protecting the underlying strata from further erosion. In this way the river would be held for a long time at nearly the same level, and would have an opportunity to swing over a wide valley floor, although the strength of the current would prevent the formation of meanders. The tributary streams would act in the same way in their lower courses, and thus the Mohave peneplain would be formed. Farther toward their heads we know that the streams flowed in more pronounced valleys, which had a depth of hundreds of feet, although the sides were of very moderate slope and thoroughly graded. In the larger valleys hard and soft strata alike were evenly truncated without reference to their texture or attitude. In the middle

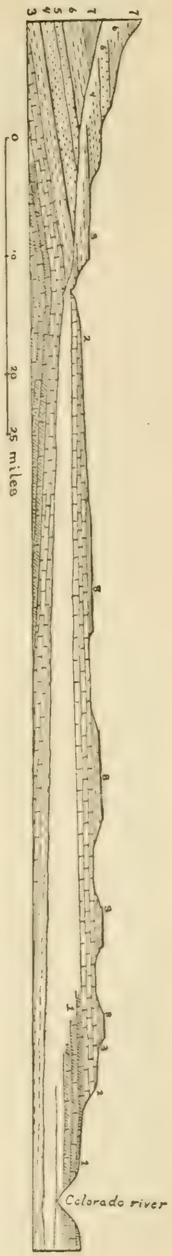

FIGURE 10.

North-south sections, from Colob to the Colorado river, showing conditions before and after the later faulting. The base-line of the sections is at sea-level. The lower section represents pre-faulting conditions; the upper one shows present conditions. 1, Red wall limestone; 2, Aubrey; 3, Moencopie and Shinarump; 4, Painted Desert and Kanab; 5, Colob; 6, Cretaceous; 7, Tertiary.

regions the soft formations were reduced to a plain which truncated the strata at an elevation determined by the local base-level. The harder, more resistant formations stood up as terraces or plateaus where they were horizontal, and as ridges or cuestas where they were tilted. In the most elevated regions the relief was very marked. In a highly resistant mountain massif, such as the Pine Valley range, standing at an elevation of eight thousand feet, there were fairly deep valleys which nevertheless did not penetrate far into the centre of the lava mass. In a plateau such as that of Colob, where relatively soft strata stood at an elevation of from five to seven thousand feet, advanced dissection was the rule, and we find great valleys penetrating far into the interior and having a relief of several thousand feet.

Two rather unexpected results arise from this restoration of the country to its pre-faulting condition, and for neither of them can we offer an adequate explanation. One is that the Virgin river, if it was then located where it now is, flowed along the broad, flat arch of a gentle anticline. It is possible that the river was shifted to its present position after the anticline was flattened out, but of this we have no evidence. Another point that attracts attention is that the anticline lies directly in line with the most massive portion of the Pine Valley lava mass, and is almost a continuation of the line where the folds of an earlier date flatten out into simple monoclines. Whether these three things are causally connected or not, is wholly unknown. Their relation suggests that the lava of the mountains acted as a great buttress, around which the sedimentary strata have been bent and plicated, just as in a tidal estuary ice is bent around the pier of a bridge.

Before leaving the subject of the condition of the country just prior to the second faulting, let us get a bird's-eye view of the whole region. From the top of the lofty Pine Valley mountains an observer would have seen to the southwest, west, and north, the low ridges of the southern part of the Basin Range province — ancient mountains, well dissected and mature, and presenting nearly the same appearance as to-day. To the east were the High Plateaus, lying considerably lower than at present, and everywhere carved into broad valleys, from which rose rounded hills of horizontal strata to a height of two thousand feet, more or less. The cliffs and canyons which are now so striking did not then exist, but in their places were long, gentle slopes, covered deeply with soil and probably with vegetation. Still farther around the horizon from the east to the southwest, the observer would have seen a smooth monotonous expanse, the Mohave peneplain, sloping slightly away to the Colorado river, and unbroken by any elevation more prominent than a subdued escarpment a few hundred feet high. Nowhere in all the broad horizon was there anything sharp or abrupt in the relief. Everywhere maturity and old age were the rule, — a maturity of strong but unobtrusive outlines, whose mountains were domes and whose valleys were broad basins filled with gravel; an old age where relief had almost vanished.

Lava Flows.

Having reconstructed the topography as it existed at the end of the inter-fault cycle, we must put off the discussion of the last faulting long enough to mention a few facts connected with the lava flows which are so important as a means of preserving the ancient surface and of measuring the extent of recent displacements. When at last the time arrived for the land to wake from its long rest and once more begin an active life of uplift and growth whereby it might enter a new cycle and renew its youth, the first warning of impending change came in a series of lava flows, the precursors of a long line of which the last was poured forth but yesterday. Our observations agree with those of Dutton and others in showing that lavas were often ejected many times from what seems to be the same vent. In some cases there appears to have been no great interval between successive flows, since there is no noticeable evidence of weathering and erosion to differentiate them. In the fault scarp above Bellevue, for instance, a section has been exposed in which are at least ten thin sheets of basalt that seem to have been poured out in comparatively rapid succession. At St. George, on the other hand, is one of the best examples of a very different type (Fig. 11). Just west of the town rises a broad flat-topped mesa of Painted Desert and Kanab sandstone capped at an elevation of five hundred and fifty feet above the town by a sheet of basaltic lava, *A*. On the east side of this, about three hundred and fifty feet below the top, lies a terrace a few hundred feet wide which, like the mesa, owes its preservation to a cap of basalt, *B*. The general level of the country on either side is now more than two hundred feet below the terrace. On the valley floor to the west is a third sheet of lava, *C*. All three of these flows seem to have come from a point a few miles to the north, although it is not known whether they are all derived from the same source. They represent the great difference in age which prevails among the products of volcanic eruptions, even though all may rightly be called recent. The oldest lava sheet, *A*, appears to have been poured out on the graded surface which characterized the country at the end of the inter-fault cycle. Then the general uplift which seems to have accompanied or perhaps preceded the recent faulting and to have raised the whole region — the western as well as the eastern side of the fault. Erosion at once became active, and valleys were cut to a depth of three hundred and fifty feet on one or both sides of the lava sheet. Then, before the uplift had been completed, or at least before the renewed erosion which it occasioned had reached a condition of equilibrium, another stream of lava, *B*, flowed down the valley east of the first. Again valleys were worn away, this time to a depth of nearly three hundred feet, and in very recent times a third lava flow, *C*, poured down the western valley. Since that time there has been further erosion along the main drainage channels, so that the first lava flow now stands some eight hundred feet above the neighboring streams. Elsewhere are even more modern lava flows, showing absolutely no sign of erosion, so that we have good evidence that there has been a continuous series of volcanic eruptions extending throughout the whole period that may be geologically called recent.

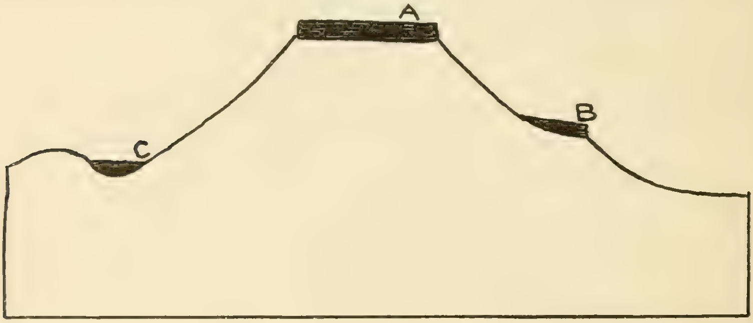

FIGURE 11.
Lava terraces at St. George.

The difference in elevation at St. George between the Virgin river and the most elevated lava sheet gives a minimum measure of the amount of uplift to which the downthrown block west of the Hurricane has been subjected. This amounts to eight hundred feet. As the river can hardly have flowed more than one or two hundred feet below the general surface at the end of the inter-fault cycle, the country must then have stood at least six hundred feet lower than now. If, however, the river had now cut down to as low a level as it then occupied, it ought to be equally well graded, but this is by no means the case. Accordingly we are justified in assuming a greater uplift than six hundred feet. In a preceding section we have put this at one thousand feet as an average for the whole region north of the Shivwits plateau. In certain places it may have been greater. A study of the map (Arizona, Mount Trumbull sheet) shows that where the Virgin river cuts through the Virgin mountains ten or twenty miles southwest of St. George it flows in a precipitous canyon of very young aspect. The gorge is incised to a depth of fifteen hundred feet in a maturely dissected mountain mass from which the young valley is almost as sharply distinguished as the Colorado canyon is from its plateau. A conclusion based only on map study cannot be final, but we believe that future observation will show that parts of the St. George block have been uplifted over fifteen hundred feet. This fact has an important bearing on the recent displacement which we shall now discuss.

The Later Faulting.

In all the foregoing consideration of the earlier faulting, the prolonged erosion, and the lava flows we have been constantly obliged to refer to the later faulting, and have spoken of it as though it were a proved fact for which we had already presented the evidence. So much, indeed, has been said that it is here necessary merely to summarize the facts, to discuss the offset by which the displacement passes from the Hurricane to the Grand Wash faults, and to point out the bearing of these facts on the history of the Grand canyon of the Colorado.

The displacement by which the Colorado plateaus were uplifted and by which the cutting of the Grand canyon was inaugurated began as a general uplift of the whole country. This is shown by the renewed dissection in the blocks west of the faults as well as in those east of them, proving that the former were uplifted with the latter, though to a less extent. Soon, however, the eastern portion of the country, which is now known as the Colorado plateaus, broke away from the western Basin Range portion and was uplifted at a more rapid rate. The displacement between these two blocks, so far as we have studied it, consists of three parts: (1) the later Hurricane fault, (2) the Fort Pierce monocline, and (3) the later Grand Wash fault. The evidence of the two faults lies chiefly in numerous displaced lava sheets. Some of these are broken sharply in two as at Bellevue, at the mouth of the Virgin canyon, and at Sugar Loaf along the Hurricane, and at the southern end of the buttes in the middle portion of the Grand wash. Others, such as those at Toquerville on the Hurricane and at the northern end of the buttes in the Grand wash, are highly flexed into attitudes which liquid sheets of lava could not possibly assume, and therefore must have been bent into their present position by movements of the crust. In addition to this evidence from lava flows the fault scarps themselves show signs of being very recent. They are almost always ungraded and precipitous, and run across country with utter disregard to structure or drainage. A third proof of recency lies in the fact that the strata on the two sides of the modern faults match perfectly when restored to the level that they occupied before the faulting took place. In regions where faulting took place long ago the outcrops on the two sides have retreated at unequal rates and do not match.

The relation of this recent faulting is well understood in the case of the Hurricane fault, where, as we have seen, the topographic results of the earlier faulting were almost entirely effaced during the long inter-fault cycle. The later faulting followed closely the general line of the other, but, contrary to what would be expected, often diverged from it slightly for long distances. Thus, though the two run closely parallel, they do not coincide, and sometimes cross one another as at Kanarra. In the Grand Wash fault the relation between old and new is not so clear, because, on account of the inaccessibility of the region, our knowledge of it is very slight. Our own observations applied almost entirely to the distinctly modern faulting. Gilbert, however (*a*, p. 54), gives an east and west section along the mouth of the Grand wash which shows that the total displacement is decidedly greater than that which our observations show to be due merely to the new fault. The logical inference is that there was an earlier Grand Wash fault corresponding to the earlier Hurricane fault. Davis (*b*, p. 147), on the basis of facts stated in Dutton's atlas and monograph, states that "while a monoclinal slice of the Trias is preserved along the thrown [western] side [of the Grand Wash fault], there is no Trias on the heaved Shivwits block for fifty miles. The Trias must have once extended eastward beyond the line on which the fault was broken, and the uplifted eastern extension of the formation must have been worn away after the faulting." The erosion which could remove such an extent of strata from the uplifted block must have required far more time than has elapsed since the recent faulting. Accordingly Davis (*b*, p. 148) infers that the Grand Wash fault, like the Hurricane, is double, one part being old, the other new. Nothing that we saw contradicts this so far as the southern part of the displacement is concerned close to the Colorado river. In the northern part of the Grand wash, however, we saw evidence of only one displacement, and that was of recent date. Apparently the old fault was of small dimensions compared to the modern one, and died out some fifteen or twenty miles farther south.

Taking up once more the recent displacement as a whole, we find that at Kanarra, the northern limit of our study, it is a true fault with a throw of two thousand feet or more. This decreases toward the south, very slowly at first, but later quite rapidly, until at Toquerville it passes into a monoclinal fold by which the lava sheet of Toquer hill is bent steeply upward some eight hundred feet. In the neighborhood of this hill the displacement is complicated by a number of small fractures, and is set off about three miles to the east in *en echelon* fashion. The amount of displacement continues to decrease until at the point where the Virgin river crosses the fault it amounts to only three hundred feet. Here, it will be remembered, lay the axis of the gentle anticline of the inter-fault cycle. Farther south the displacement again increases for ten or fifteen miles until it amounts to fifteen hundred feet. It then decreases, and south of Fort Pierce almost wholly disappears along the line of the Hurricane. This does not mean, however, that the displacement is lost. It merely turns from a north and south course and goes southwestward. Instead of being a sharp fault it takes the form of a long gently sloping monocline which descends toward the northwest. The northern limit of this slope lies a few miles south of the Virgin river; its southern limit extends from south of Fort Pierce to Black Rock. At the latter point the line of displacement again turns south, at first merely as a syncline and then as a true fault, the throw of which increases until at the Colorado river it is over five thousand feet. Black Rock is a central point, on every side of which there was uplift. To the south and east the strata were uplifted smoothly and form part of the upheaved plateau block. On the other sides they were uplifted in the form of a very flat cone one-third of which is replaced by the horizontal strata. It is as though most of the plateau block had been cut apart from the St. George block, but this one part remained attached, and when the eastern block was lifted up it pulled a corner of the western block up with it. The deep cutting of the Virgin canyon where that river passes through the Virgin mountains a dozen miles north of

Black Rock seems to indicate that in this portion of the St. George block such an extra uplift took place.

The relation between the upheaval of the Colorado plateaus and the cutting of the Colorado canyon has been explained time and again. Previous to the faulting the river flowed close to the level of the land surface as a whole. Its course at that time may have been in general consequent, as Davis has pointed out (*b*, pp. 158–167), but as yet we cannot fully restore the topography and structure of the entire region previous to the last faulting, and so cannot be certain on this point. When the plateaus were uplifted the rate of motion was so slow that the Colorado was able to intrench itself without appreciable change in its location, although the slight relief of the Mohave peneplain would not have been sufficient to prevent the river from shifting northward toward the Virgin had the uplift been very rapid. As it was, the Colorado cut for itself a deep trench along a course which, however consequent it may have been in the inter-fault cycle, seems to be strictly antecedent so far as the present canyon cycle is concerned.

Minor Faults.

In addition to the great faults along the border between the Plateau and Basin Range provinces, there are two minor faults in the vicinity of Toquerville. In both of these, as in all the known displacements of the region, the uplifted portion lies on the eastern side. The age of these is probably the same as that of the neighboring major faults, since they present what appear to be the same characteristics in respect to amount of dissection, agreement of outcrops on the two sides, and relation to the pre-faulting topography.

One of the two faults lies in the St. George block, a short distance east of the town of Washington. Its course is south-southeast for about ten miles from the foot of the Pine Valley mountains to Fort Pierce. Its northern end was not closely examined, but toward the south it was seen to lessen gradually until it passed into a well-rounded anticline, which in turn seemed to flatten out entirely where it meets the Fort Pierce monocline nearly at right angles. The fault is best exposed close to the Virgin river, where its throw is at a maximum. It here crosses the diagrammatic breached anticline of Leeds (p. 219), and has dropped the west side so far that for a distance of two or three miles the Shinarump ridges are buried in silt brought down by the river. An interesting feature of this displacement is that its point of maximum throw lies very nearly in line with the point of minimum throw of the Hurricane fault. It may be a purely accidental coincidence, but as the main fault increases both north and south of this point to its normal throw the smaller sub-parallel fault decreases.

The second of the two minor faults lies in the Colob plateau, one of the loftiest portions of the upheaved eastern block. It trends a little more to the east than does the main fault, which here trends north-northeast. Toward the south it swings around still more to the west and dies out. In the escarpment of the Hurricane fault just north of Dry canyon a mild syncline appears, which seems to be the last remnant of the Colob fault. Along the line of maximum displacement, which amounts to seven or eight hundred feet, runs the upper part of LeVerkin creek for a distance of two or three miles. On the west of the stream the downthrown block, which might much better be called the less uplifted block, rises three hundred feet or more in steep but graded slopes covered with vegetation. On the east its edge presents a precipitous cliff of naked red sandstone which rises a thousand feet and is capped by a band of white, the Colob sandstone, and a band of green, the luxuriant vegetation that flourishes on the top of the well-watered plateau. A few miles from its source, LeVerkin creek leaves the line of the fault and plunges through the uplifted block in a chasm of profound depth and exceeding narrowness. The brevity of our visit to this region gave an opportunity for nothing but a hasty reconnaissance. It sufficed, however, to show that the tilted block between the Colob fault and the main Hurricane presents a type of topography different from any that we have elsewhere encountered. Here alone we find ponds, small sheets of water which during the rainless summer have no visible outlet. They lie in longitudinal valleys which seem to be of subsequent origin, as they run north and south parallel to the prevailing strike of the whole region whose strata here dip to the east. The present drainage, however, is largely consequent on the recent faulting, and seems to have no relation to the little basins that lie athwart it. In our brief traverse of the region we got the impression that at the time of the Colob faulting this block was tilted in such a way that an old subsequent drainage was entirely destroyed and a new consequent system inaugurated. Here and there, however, the old valleys were warped or dammed in such a way that they formed little basins between the headwaters of the younger streams. This region, together with the adjacent portion of the Hurricane fault north and south of Kanarra, and the neighboring Cretaceous with its abundant coal and fossils, affords a fine field for a summer's geological study. Not only are there most interesting problems to be worked out, but there is the finest of scenery and a delightfully cool invigorating climate, utterly different from the sultry desert of the lower plateaus and valleys.

The Post-Fault or Canyon Cycle of Erosion.

The Normans relate an Indian tradition that long ago there was snow all the year round on the Pine Valley mountains, although it does not now come until November and is gone in June. Also, the valley of Ash creek was smoother than now and had no canyon: a great flood came and washed it out. Whether these are pure Indian traditions or an adaptation of the remarks of some early white explorer, we could not ascertain. If it is the former it is highly significant, and even if it is the latter it is essentially true, though less interesting. The canyon cycle must include at least the latter part of the glacial epoch, although no traces of glaciation have been noticed in our immediate district. It certainly has witnessed the change from the relatively smooth topography of the inter-fault cycle to the rough topography of the present. How much of this change occurred after man appeared on the earth has not been determined, but erosion proceeds so rapidly in this naked country that it is quite possible that a considerable portion of the work of the last cycle has been done since the first human inhabitants settled here.

The work of the Canyon cycle has consisted chiefly of the removing of weak strata that were formerly below sea-level, the cutting of deep canyons, and the steepening and renewal of cliffs. All these features are illustrated in the accompanying diagrams (Fig. 12), in which *I* represents the conditions previous to faulting, and *II* those of the present. In the first sketch, the Carboniferous series, *A*, and the overlying Moencopie shales, *B*, had been reduced to a peneplain, the surface of which is shown by the line *HI*, and on this had been ejected a lava flow, *G*. Farther north the same soft shales were protected by the hard Shinarump, *C*, with the result that there was a long gentle slope from the peneplain upward. Among the higher strata the soft Painted Desert series, *D*, and the hard Kanab sandstone, *E*, formed another slope of equally gentle ascent rising to the upland, *F*, of Colob and Cretaceous strata. At *H* and *I* were two rivers flowing toward the west in insignificant valleys. When the country was uplifted to the position which it now occupies, rapid changes began, which up to the present have gone far enough to produce the young and vigorous topography of *II*. The hard Carboniferous strata, *A′*, have been but little affected except in the immediate river valleys, where deep narrow canyons, *I′* and *H′*, have been cut with very precipitous sides. The overlying soft strata, *B′*, have been entirely stripped off except where they are buried under lava and form mesas, *G′*, or where they are protected by the Shinarump, *C′*. In the same way the Painted Desert strata, *D′*, have been removed, and the overlying hard Kanab, *E′*, forms cliffs. To-day these cliffs are rapidly retreating but erelong talus from the upper hard layers will so cloak the lower soft layers that the slopes will become more moderate and the retreat of the cliffs much slower.

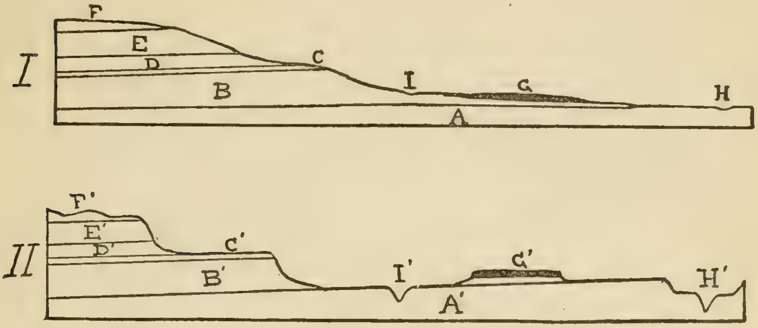

FIGURE 12.

North-south sections to show the work of the present cycle.

The best example of the stripping of soft strata is the great Carboniferous platform, in which is cut the canyon of the Colorado. Here, over an area of hundreds or even thousands of square miles, a few hundred feet of Moencopie shales have been stripped off, as is shown by the unconsumed patches remaining here and there, and by the larger masses preserved under lava caps. Although the most notable feature of the cutting of canyons is the Grand canyon, others, such as that of the Virgin river, are worthy of mention. An interesting case is that of Ash creek, which now flows in a shallow canyon at the foot of the Hurricane fault north of Toquerville. As this is part of the downthrown block, the amount of cutting has naturally been less than in corresponding cases on the other side of the fault. The notable feature, however, is that a short distance west of the present canyon is another of about the same size which is now dry and lies on the crest of an arched sheet of basalt

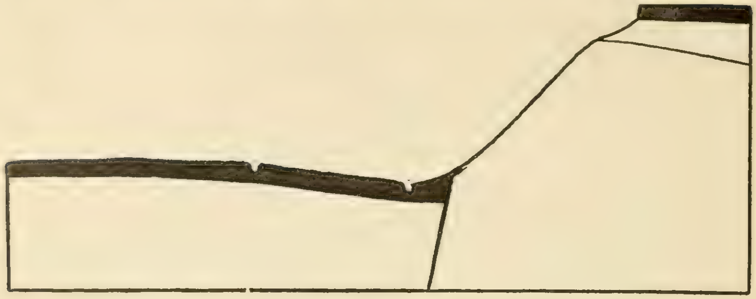

FIGURE 13.
The canyons of Ash creek, near Toquerville.

(Fig. 13). Apparently Ash creek cut the latter canyon before the last faulting, although possibly after the premonitory upheaval. At the time of the faulting the lava sheet was bent and the creek was tipped out of its old channel to the recent one. Renewed cliffs are everywhere the rule, although the most striking examples are the far-reaching lines of the great Pink, White, Vermilion, and Chocolate terraces.

Of the three processes — namely, the stripping of soft strata, the cutting of canyons, and the formation of cliffs — the first and last two are now in a state of great, perhaps maximum, efficiency, while the first is already almost completed. The combined result of the three is a region of strong contrasts, where the three elements — canyons, plains, and cliffs — are utterly different, and yet all in their freshness and nakedness bear the stamp of newness and of a dry climate. But this is not everywhere the case, for in the Colob plateau the ancient mature topography is still preserved, and acts as a foil to set off the new. Yet it is the latter that is impressive. Old slopes have been revived and steepened; enormous tusks of massive red sandstone have been carved out of the once continuous upland (Plate 1 B), and deep canyons marvellously narrow and steep have been sawed far into the depths of the plateau. One of these, that of LeVerkin creek, is so cleft-like that for several miles, where the depth is over fifteen hundred feet, only a narrow strip of sky thirty degrees wide can be seen, and sometimes this is reduced to fifteen degrees. In many places the walls overhang the tumbling brook at a height of several hundred feet, and forever prevent the sun from penetrating to the cool depths, which, after the hot, verdureless glare of the lowland desert, seem ideal in their delightful dampness and abundance of vegetation. Often the bottom of the canyon is so narrow that pine trees, overturned by wind or flood, have not room to fall flat, but lie against the red sandstone walls, forming bridges under which the trail winds upward along the rough valley floor. Yet, in spite of the depth and impressiveness of the canyons, erosion has accomplished but little since the last upheaval, even although it almost seems that the young canyons are visibly sawing back into the massive stump of the plateau. Their rapid work gives promise of the day when, if erosion continues unchecked, the mature topography must be entirely consumed, and a rugged, inhospitable region will succeed the attractive pasture of the upland of to-day. But that will by no means be the end; for, if the present cycle is allowed to run its course unhindered, a gentler maturity and a subdued old age are still in store for this desert corner and for all the great Southwest.

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EXPLANATION OF PLATES.

PLATE 1.

A. West Temple of the Virgin. Photograph by W. M. Davis. The view looks southeast across the Virgin canyon near Rockville. The broad Shinarump platform is seen in the immediate foreground and across the canyon. Beyond it rises the red sandstone "Temple," cut by deep vertical rifts. Halfway up from the Shinarump platform is the bench of sandstone that caps the Painted Desert shales. Landslide hummocks below this bench show that undermining is actively going on.

B. "Rhinoceros head." Photograph by W. M. Davis. A corner of the red Kanab escarpment, northeast of Toquerville. The view looks southeast from near Dry canyon, toward the extreme southwestern salient of Colob, — a magnificent red sandstone promontory with a tusk-like apex.

PLATE 2.

A. Up Dry canyon. Photograph by W. M. Davis. The view looks east. The cliffs and pinnacles in the distance are red Kanab sandstone. The head of Dry canyon is on the left. On the right rises the cuesta of Painted Desert shales, with its cap of hard sandstone.

B. Anticlinal hill near Leeds. Photograph by W. M. Davis. Looking southwest over the town, one sees the western slope of the cigar-shaped anticlinal nose. On the left the entire Shinarump arch is preserved, but from the centre of the picture southward one sees only the western half of the breached anticline stretching off towards St. George.

PLATE 3.

A. The Hurricane fault-scarp near Toquerville. Photograph by W. M. Davis. Seen from the road to Virgin city, looking north. Here the fault has nearly died out. Against the vertical face of Aubrey limestone on the right can be seen the gently inclined layers of Moencopie shales of the downthrown side.

B. The Hurricane cliff at Virgin canyon. Photograph by W. M. Davis. Looking southeast, one sees the canyon in the centre of the picture. The steep scarp marks the recent faulting along the Hurricane. On the uplifted side is a flat bench of lava over soft Moencopie shales. Just beyond this bench rise low mature hills of hard Aubrey limestone, — relics of ancient topography along the earlier Hurricane fault line, which acted as a barrier to the basalt when it flowed eastward across the old fault line. In the foreground is a gravel plain covering the lava on the downthrown side of the recent fault. The ruggedness of this fault is shown by the series of "splinters" of lava along the cliff front, just north of the canyon.

PLATE 4.

A. Cliffs near Zion. Photograph by W. M. Davis. Lofty peaks of red Kanab sandstone with white Colob sandstone above.

B. Rock sculpture in Virgin canyon. This view south over Rockville shows something of the characteristic form of each member of the series, from Moencopie to Kanab. In the foreground is the flat-floored valley of the Virgin, with the little Mormon town and its irrigated fields. The bad-land topography of the soft Moencopie shales shows in systematic spurs that run down from the Shinarump platform in the middle of the picture. This platform is banked by landslides of Painted Desert. In the distance is the high cliff front of red Kanab sandstone, showing the characteristic vertical rifts. The bench-maker at the top of the Painted Desert shows distinctly on the left.

PLATE 5.

A. Pleistocene gravels in the Grand wash. The gravel deposit is now being excavated by erosion. The larger boulders are basalt; the smaller are sandstone and limestone.

B. The two faults at Kanarra. The view looks northeast. The new fault forms the prominent escarpment; the old fault passes from x to y, where it cuts the new one. The strata to the left of x are inverted and dip to the northwest; those to the right are normal and dip gently to the east.

PLATE 6.

Cross-sections to accompany map of the Toquerville district. Drawn to scale; no vertical exaggeration.

PLATE 7.

Geological map of the Toquerville district. Topography and geology by E. Huntington and J. W. Goldthwait. The contour interval is 200 feet.

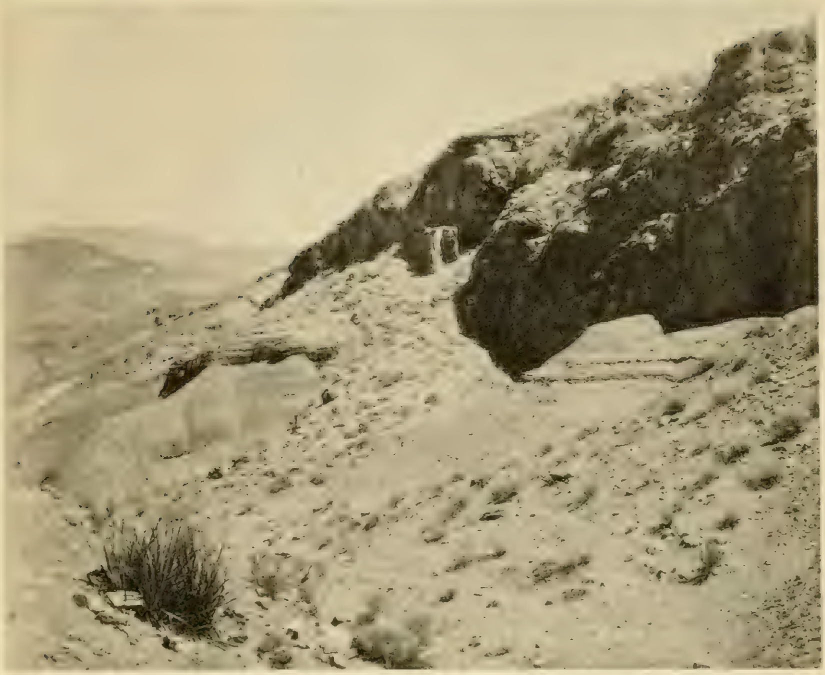
A. WEST TEMPLE OF THE VIRGIN.

[illegible]

B. [illegible]

A. UP THE CANYON.

B. [illegible] VALLEY.



A. THE HURRICANE FAULT-SCARP.

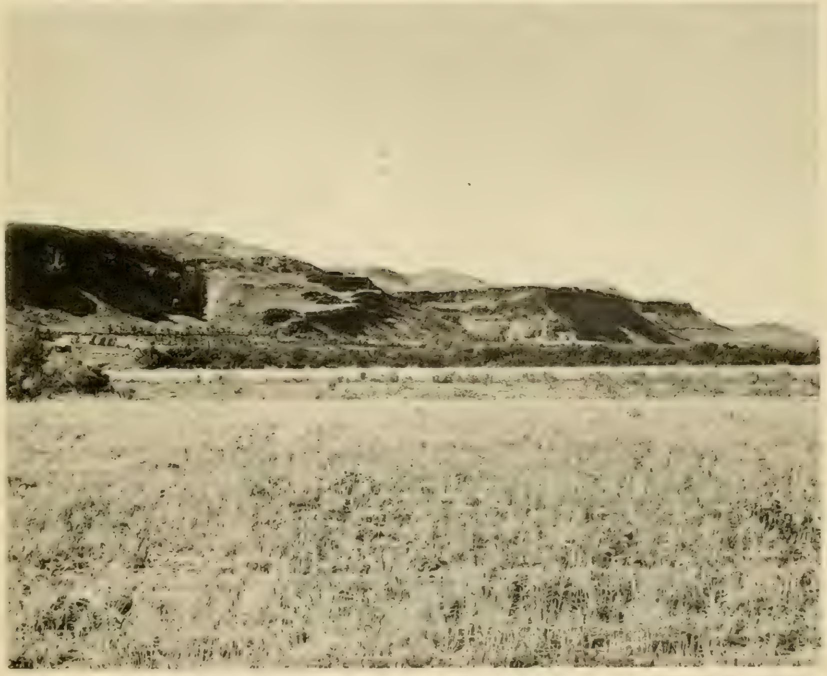
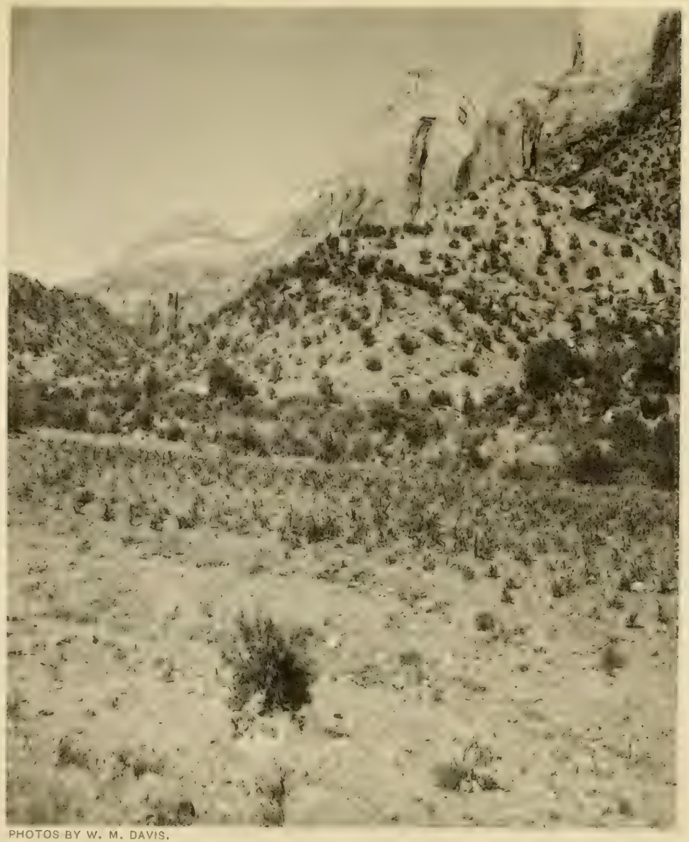


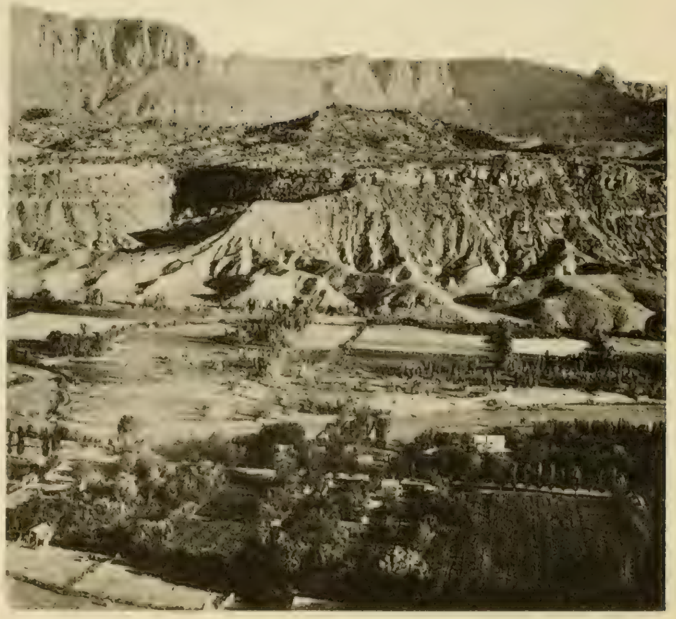
PHOTO BY W. M. DAVIS. HELIOTYPE CO., BOSTON.

B. THE HURRICANE CLIFF AT [illegible]



PHOTOS BY W. M. DAVIS.

A. CLIFFS OF ZION.



HELIOTYPE CO., BOSTON.

B. VIEW SOUTH OVER ROCKVILLE.

A. PLEISTOCENE GRAVELS.

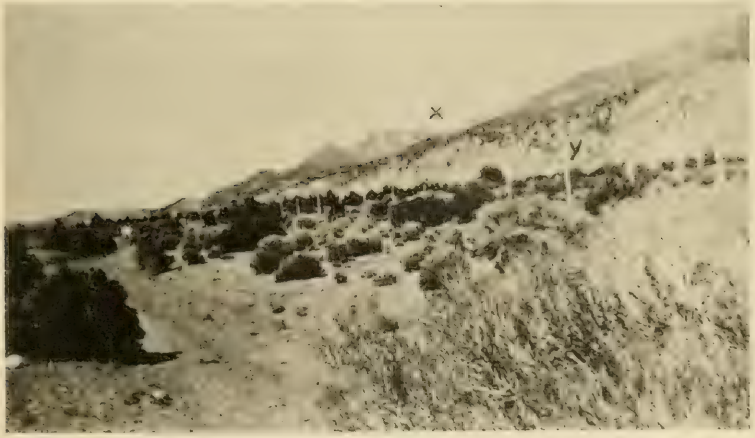
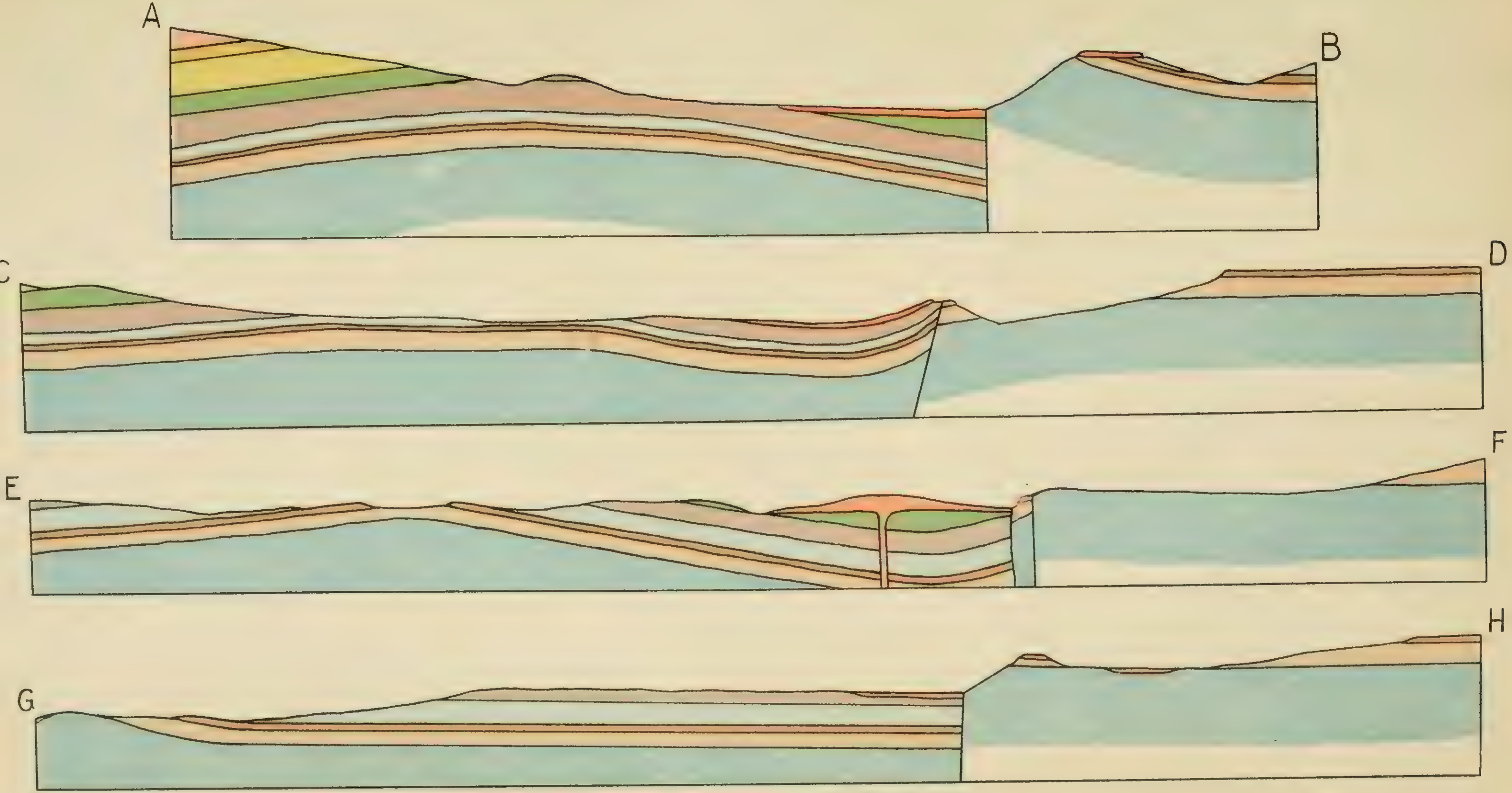


PHOTO BY W. M. DAVIS. HELIOTYPE CO., BOSTON.

B. THE [illegible] FAULT AT [illegible]



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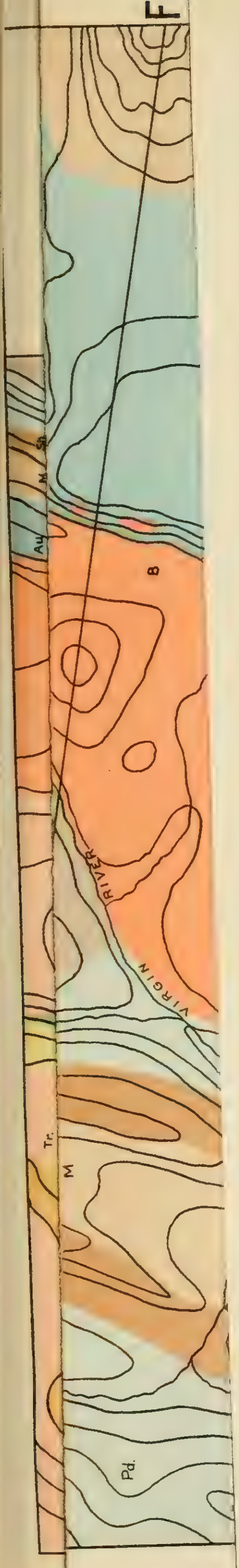
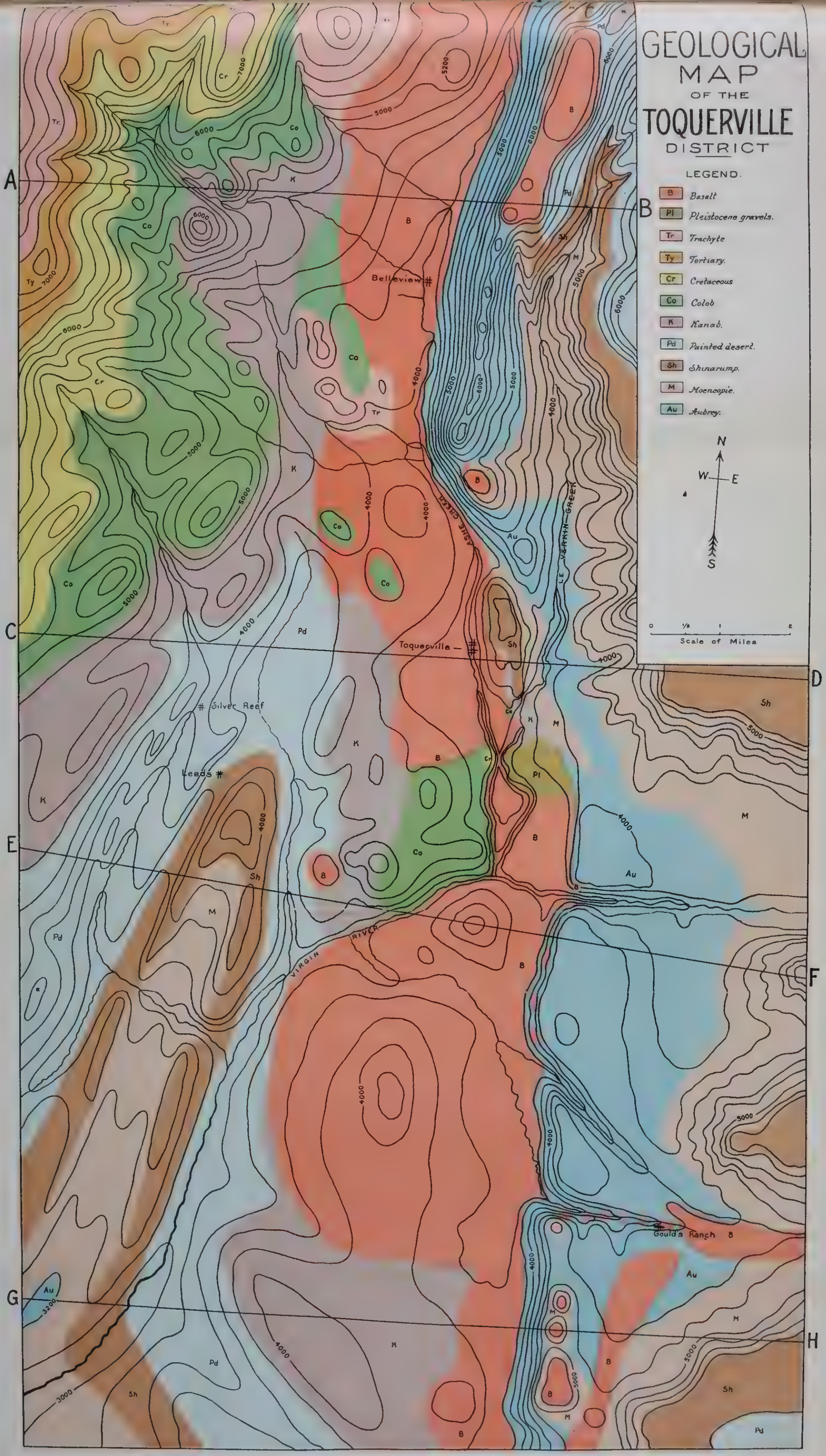

F
Sh
M
Au
B
VIRGIN RIVER
Tr.
M
Pd.



GEOLOGICAL MAP OF THE TOQUERVILLE DISTRICT

LEGEND.
B Basalt
Pl Pleistocene gravels.
Tr. Trachyte
Ty Tertiary.
Cr Cretaceous
Co Colob
K Kanab.
Pd Painted desert.
Sh Shinarump.
M Moenoopie.
Au Aubrey.
N
W
E
S
0
1/2
1
2
Scale of Miles
A
B
C
D
E
F
G
H
Belleview
Toquerville
Silver Reef
Leeds
Gould's Ranch
ASHE CREEK
LE VERKIN CREEK
VIRGIN RIVER
3000
3200
4000
5000
5200
6000
7000

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THE SAND PLAINS OF GLACIAL LAKE SUDBURY.

BY JAMES WALTER GOLDTHWAIT.

WITH FIVE PLATES.

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No. 6. — *The Sand Plains of Glacial Lake Sudbury.*

BY JAMES WALTER GOLDTHWAIT.

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Introduction.

ALTHOUGH sand plains have received much attention from geologists in New England, it is only of recent years that the grouping of these deltas and their relative altitudes have been studied in a detailed way, with the purpose of tracing the history of the ice-front lakes in which they were built. The work done by Professors Crosby and Grabau, and by Dr. Clapp, has shown the possibilities offered by such a study. During the academic year 1903–1904, as a graduate student under Prof. W. M. Davis of Harvard University, I undertook a study of the sand plains of the Sudbury valley, twenty miles west of Boston. My purpose was to investigate the grouping of sand plains in a single drainage basin, with greater accuracy in the determination of levels than had hitherto been attempted. The chief result of the work, as will be seen, was the discovery that the sand plains of this district do not conform to the horizontal step scheme of grouping used by Crosby and others for the neighboring extinct lakes Nashua, Charles, and Bouvé; but that they seem rather to record a postglacial tilt, by which their original relations of level have been upset.

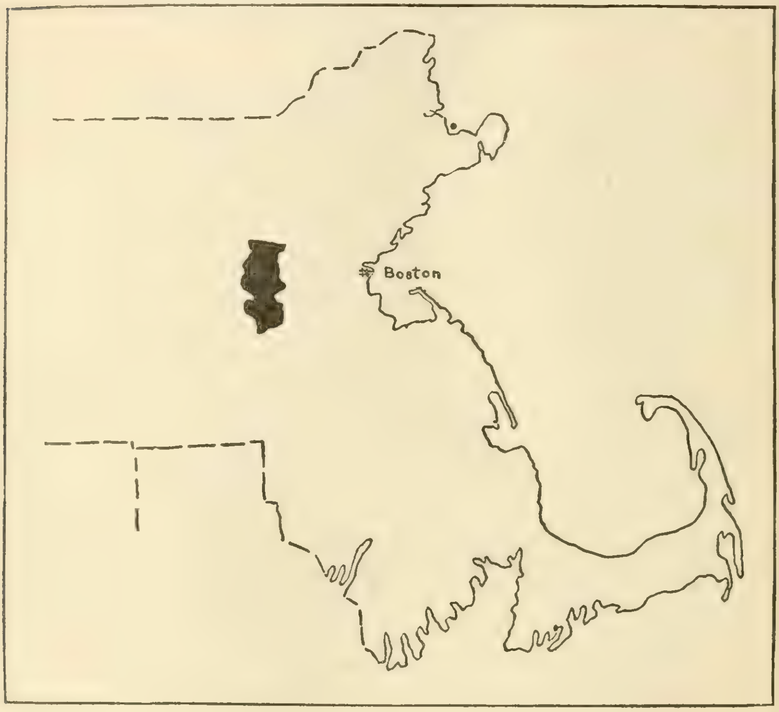

FIGURE 1.

Sketch map of eastern Massachusetts showing location of Lake Sudbury.

I shall first review the conditions under which temporary glacial lakes might form, and the probable history they would undergo; passing then to those physiographic features which mark extinct ice-front lakes, especially sand plains, I shall consider the horizontal step scheme of arrangement of deltas used by Professor Crosby and others; and finally, applying this scheme to the data from the Sudbury valley, I shall show that the sand plains of Lake Sudbury do not fall into flat steps, but probably into a tilted step-system.

Conditions of Drainage along the Front of the Retreating Ice-Sheet.

When the ice-sheet melted back over New England, uncovering a land surface of gentle irregularity, the country along its front must have met with temporary conditions of drainage quite unlike those of the present day. The ice must have blocked the courses of many streams, turning them one side or damming them up to form temporary lakes. The melting of the ice itself doubtless contributed in a measure to the volume of the streams in front of it, although the rate of melting may have been so slow that there was only a moderate flooding of the streams.

Where the ice-sheet lay with its front along a divide between two stream systems, or on ground that sloped away from it, there was opportunity in a given time for either an unusual amount of erosion or an unusual amount of deposition. Each stream that drained away from the ice would from the beginning attempt to make an evenly graded bed for itself, either degrading or aggrading according to the conditions of load, volume, and slope: the greater the supply of waste, the stronger the tendency to aggrade; the steeper the slope, the greater the power to erode. An ice-fed stream which was given little waste to carry, and which ran down a steep slope, would be very active in eroding, while another stream which received an abundance of waste gravels, and which ran down a gentle slope, would be active in aggrading. In the first case, the resulting physiographic feature might be a slope or a channel swept clean of all but boulders, coarse gravel, and bed-rock ledges; in the last, it might be an alluvial fan or a waste-filled valley.

As soon as the ice had melted back of a divide, so that its front lay across the lower part of a valley, it enclosed a basin whose margin was in part the ice-wall and in part the high ground which formed the watershed of the valley. Inasmuch as each of these basins was originally covered by the ice-sheet, and was uncovered by its melting off, each must always have contained water up to as high a level as the lowest point on its rim; for each of these low points, or "cols," would have served as an outlet to drain off the excess of water in the adjoining basin. Besides the water derived from the melting ice, whatever water was shed into the basin by ordinary process of rainfall must have aided in keeping it filled to its capacity.

I propose now to trace the steps which an ice-front lake of this sort might be expected to pass through as the ice retreated.

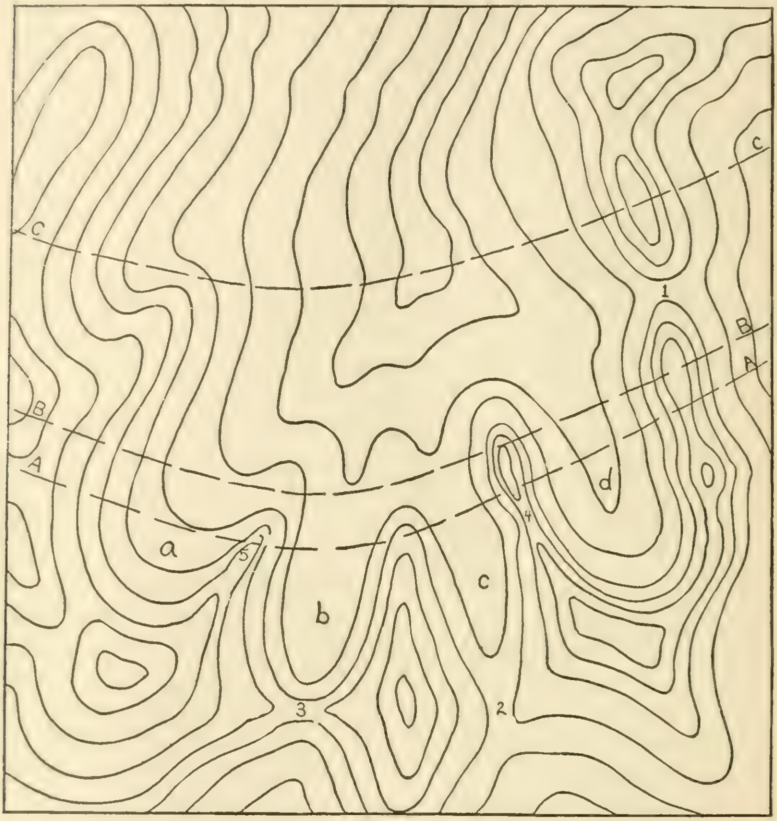

FIGURE 2.

Diagrammatic contour map to show developmental changes in a temporary ice-front lake.

Life History of a Temporary Ice-Front Lake.

When the ice stands just back of a divide, it will form many little lakes at different levels. From the fact that valleys branch and rebranch headwards so that the number of little valleys is greatest near the divide, it follows that the closer the ice-wall is to the divide, the more little valleys it will shut in, and the more little lakelets there will be. Since also it is probable that the cols at the heads of these little valleys have different altitudes, the lakelets formed at this stage of ice-retreat will not only be many in number, but will have different levels. Thus in the diagram (Fig. 2) the ice standing with its front at A . . A, north of the divide, shuts in four lakelets at different levels, indicated by the figures 2, 3, 4, 5. Lakelets *b* and *c* overflow across the main divide through cols which have altitudes 3 and 2 respectively. It may happen, however, that a lakelet finds its lowest outlet through a col in a secondary divide into an adjacent lakelet or across a secondary divide directly at the ice-front. The latter is notably the case in the temporary ice-front lakes of western New York, described by Fairchild (a, b, c, d, e, f). In the diagram, lakelet *d* drains westward into *c*, through a col 4 in the secondary divide which separates these two lakelets; also, lakelet *a* flows eastward into *b*, across the dividing spur directly at the ice-front, at the level 5. Many small lakelets, then, at different levels, characterize the first stages of withdrawal of the ice from a divide.

As the ice-front melts back, it will retreat beyond the junction of certain of the smaller headwater valleys, so that the separate lakelets originally shut in, in those valleys, will merge into a single lake. Thus, in the figure, when the ice has withdrawn to B . . B, lakelets *b* and *c* will coalesce. As the two lakelets unite, the higher one will drain down to the level of the lower, leaving its old outlet high and dry. At the moment of coalescence, the submerged area will of course be equal to the sum of the two original lakelets; but as the level of the higher one falls, the submerged area is partly reduced in extent, in a measure depending on the amount by which the higher lakelet is lowered, and its shallowness. Thus in the figure, when at stage B . . B lakelets *b* and *c* unite, the level of *b* will fall from 3 to 2, the old outlet at 3 being abandoned, and its shore-line will contract to fit the lower contour. Still, under ordinary conditions, the lake of coalescence will be larger than either of the two original lakelets, for it contains all of one and part of the other. If, however, the outlet of the lake of coalescence is below the level of the bottom of the higher lakelet, it will drain the lakelet dry, and the lake of coalescence will then be no larger than the original lakelet was at the time the two united. In the figure, the total disappearance of a lakelet, due to coalescence with a much lower one, is shown by lakelet *a*, which between stages A . . A and B . . B falls from level 5 to assume the level of the lake of coalescence, which is 3, and later 2, draining dry, however, because the new level 2 is below its lakelet bottom. Early in the withdrawal of the ice from the divide, then, there is a coalescence of the many original lakelets into a smaller number of larger lakes; some lakelets are wholly drained off. Lakes increase in size, and decrease in number. At the same time, they come more nearly into an agreement of level, the higher levels being abandoned for the lower.

Besides this merging into larger lakes, as the ice retreats from a divide, characteristic of early stages, there soon begins a succession of lowerings of level, brought about by the uncovering of lower cols in the rim of the basin. Each time a lower col is uncovered, a new outlet is formed, and the lake-level falls accordingly. So while the lakes are gaining steadily in area, during the withdrawal of the ice boundary, they are always liable to a loss in area through the lowering of the water-level to fit a new outlet. Thus in the diagram, by the retreat of the ice-front from B . . B to C . . C, the lake gains in area; but since during the retreat a lower col has been uncovered, at level 1, the water-level of the lake has fallen, and there has been a consequent loss in area. In this case, the gain through withdrawal has been greater than the loss by lowering of level. With continued withdrawal, then, there are both gains and losses in area, and successive lowerings of water-level to fit new outlets.

Changes of this sort will go on in the ice-dammed lake until at last the ice abandons the basin and allows the natural drainage to take its place.

Factors which control the Stability of Ice-Front Lakes.

The slower the rate of withdrawal of the ice-front, the longer will the lakes maintain their level and their form; for it is through withdrawal that new outlets are opened and lowerings of level are brought about. The distance from an active col outlet to the next lower one, which will replace it in draining off the water, also controls in part the permanence of form and level of the lake. Again, the strength of material over which the overflow takes place — whether it be till or bed-rock — will affect the permanence of level of the lake, and therefore its form; for if an outlet is actively cutting down its bed, it is lowering the level of the lake which it drains.

The permanence of lake-levels is of great consequence to us, for on it depends the degree of development of all those features which bear record of the lake's history. The longer a water-level is maintained, the greater and the more perfect will be the development of lake-shore forms and deltas, and the more data will be accessible for reconstructing the water-planes which they mark.

Physiographic Features which mark Water-Planes in an Ice-Front Lake.

The features which one may look for as evidence of an extinct ice-front lake are briefly these: —

(*a*) SHORE-LINES, marked by beaches and bars, or by escarpments and benches, built by the waves of the lake wherever the material is non-resistant enough, the exposure great enough, and the level of the lake permanent enough. Benches and bars of this sort are wonderfully well developed along the shores of the great lakes of the ice age, like Bonneville and Agassiz; they are easily traced along the shores of Lakes Chicago, Algonquin, Warren and Iroquois; and they are fairly well shown in New England in the Contocook valley near Hillsboro, N. H.

(*b*) OUTLET CHANNELS, cut across cols or spurs by overflowing waters, wherever the material was weak enough and the outlet was maintained long enough. The remarkable dry gorges of Lake Warren, near Syracuse, N. Y., are fine examples of outlet channels (Fairchild; a, b, c, d, e, f). Another is the valley of the Illinois River, cut by the outlet of Lake Chicago.

(*c*) LAKE BOTTOM DEPOSITS. The finer clays and silts which are fed into the lake will be carried far out, and may settle to form a horizontally stratified deposit. Silt deposits of this nature have been described by Upham in his accounts of glacial Lake Agassiz (d, 20–25).

(*d*) DELTAS. Wherever a stream enters one of these lakes, there is opportunity for a delta to form, provided the supply of waste is too rapid or too coarse for the waves of the lake to wash it away, and provided there is time enough. These deltas are large features in Lake Agassiz (Upham; a, d); and in the New York lakes described by Fairchild fine deltas were built where outlets from one lake entered the next (Fairchild; e, 38, 39, 52, 59).

(*e*) SAND DELTAS, or SAND PLAINS. These are deltas of a special class, and of such importance in New England that they deserve separate treatment. A brief description and discussion of them follows.

Sand Plains—their Form and Structure.

Sand plains are delta-like deposits of sand and gravel, built out from the ice into standing water at its front. The fact that gravels swept out from the melting ice occur thus, in isolated patches, rather than in a vaguely continuous sheet over the whole region, indicates that the drainage near the edge of the ice-sheet was systematic enough to allow the concentration of waste at occasional favorable points along its front.

In their broader features of form and structure, sand plains resemble deltas built under ordinary conditions, by streams entering a body of standing water. Like normal deltas, they have a nearly flat, gently sloping surface, the "top slope," and an outer or free border, the "front slope," which slants more decidedly and is lobate in form; in composition, the material becomes noticeably finer towards the free border; in structure, the sand plains show inclined beds below with horizontal beds of coarser material above. Yet while sand plains are delta-like in these respects, the peculiar conditions under which they are built give them certain very definite characteristics not common to ordinary deltas. Instead of being fan-shaped deposits built out from lake-shores by single streams, sand plains are more often semi-elliptical in outline, as if built out continuously from the ice for some distance along its front by many streams. In fact, they are most irregular in plan.

The headward border of a sand plain, moreover, is not the lake-shore border of a common delta, but an "ice-contact" or "back slope," which marks the position of the ice-front against which the gravels were laid down. Inasmuch as the back slope shows exactly where the ice-front was when the sand plain was built, it is a great help in determining the ice boundary of the ice-front lake at that time. In linear extent the back slope is straight or irregular, according as the ice-front was straight or irregular. In surface form it may be a simple straight slope of from 30 to 45 degrees, — the natural slope or "angle of repose" assumed by the gravels when their ice support was removed by melting. It is frequently broken, however, by hollows or kettle-holes, where isolated blocks of ice were enclosed in the gravel, and occasionally the ice-margin of a plain is wholly a belt of knobs and kettles, indicating an irregular ice-front where deposition took place among ice-blocks or upon a thin irregular ice-margin. In some cases, also, the ice-border is marked by a high moraine which rises above the surface of the plain, and is bounded on the back by the usual steep ice-contact slope. More typically, however, the back slope meets the top slope of the sand plain at a sharp angle or shoulder. At the back of the plain the material is coarsest, — usually cobbly gravel with boulders, which have reached the ground either by tumbling or melting from the ice.

The top slope is often so flat as to appear like a level plain; but usually there is a perceptible slope, 3 to 5 degrees, from the ice-border towards the free border. Near the back of the plain, kettle-holes are common, forming depressions in the top slope; near its front the plain is flattest, often unbroken save for shallow depressions which lead down to interlobate hollows, and which seem to indicate partial scouring, subsequent to the building of the plain. Cross-sections through the body of the plain generally show a decrease in size of material towards the front, with also a decrease in thickness of the topset beds.

The front slope, in cases where lobes are well developed, meets the top slope at a low obtuse angle, forming the "brow" of the lobes. This point is important, because it indicates the level of the water in which the delta was built, the flat above the brow being almost wholly of subaerial construction and the front slope sub-aqueous. Often, however, the development of lobes is imperfect, or even entirely wanting, on account of the shallowness of the lake, the irregularity of its bottom, or to the building forward of the plain to meet the shore or an ice-border.

Eskers.

Associated with these ice-bound delta deposits are usually ridges of gravel, eskers, which mark the courses of streams that fed the deltas. That these are often subglacial deposits is now recognized by most geologists. They concern our problem chiefly in so far as their position shows an area covered by the ice at the time they were formed, as their general direction indicates the general direction of the ice-front, being naturally perpendicular to it, and as their maximum height shows approximately the maximum height of deltas for the same stage of lake level. For a good description of sand plains and eskers, see Grabau (565–567, 574–578).

Significance of Sand Plains.

In what ways do sand plains, singly and collectively, throw light on the history of the retreat of the ice-sheet?

In the first place, their ice-contact borders give exact locations of the ice-front at the stages they represent. Taking a single sand plain, one can of course reconstruct only a small fragment of ice-front, and can hardly get a fair idea of the whole ice-dam; but by locating and mapping the back slopes of all the sand plains in an extinct lake basin, the fragmentary evidence may be found to fall into so systematic a scheme that it is possible to reconstruct with some accuracy successive lines of ice-front clear across the basin. The alignment of back slopes of two or more neighboring sand plains of the same level is not infrequently so pronounced that one may fairly assume that the back slopes of these deltas represent portions of the same ice-wall; and when these back slope lines, extended across the basin, connect with morainic patches on its rim, crossing the rim at points that allow an overflow-outlet at the level of the deltas under consideration, the inference of a continuous ice-dam along the line thus traced seems quite safe. If, on the other hand, in going northward one crosses rapidly a succession of deltas whose back slopes extend east and west, the inference is strong that these deltas were not formed at the same time, but successively, as the ice withdrew.

Secondly, the levels of the lobe brows of the sand plains give an accurate measure of the levels of the temporary lakes in which they were built. The lobe brow measures the water-plane for the stage during which the lobe was built. A group of deltas of just the same altitude in a single basin probably belong to a single lake, whose level remained at that height at least so long as these deltas were being formed. The possibility of there having been several neighboring lakelets at identical levels should, however, be recognized and tested by an examination of the topographic conditions and ice-border evidence. If two deltas are at different levels, they probably represent different lakes, or different stages in the same lake, — higher and lower water-planes, — unless there have been post-movements of the land, such as tilting. The question of the arrangement of sand deltas of different levels, and the light that it may shed on the history of a lake, will be considered later (p. 273).

Certain features peculiar to individual sand plains are significant in showing how the ice retreated, its rate of melting, changes in lake-level, etc. That sand plains were built very rapidly — much faster than the ice melted back — is shown, for instance, by the extremely small ratio of backset beds to topset and foreset beds, as first pointed out by Professor Davis (a, 199). Kettle-holes, so commonly marking the places where ice-blocks were enclosed, or even buried in deposits of gravel and sand, have likewise been recognized as evidence that deposition was much faster than ice-melting.

In certain cases, sand plains show a twofold level, having two sets of lobes, a higher and a lower set. These may fairly be taken to indicate a change of level of the waters while the delta was being built. The often observed fact that topset beds truncate the upper parts of foreset beds is believed by Professor Woodworth and others to indicate a change of level, giving a true erosion unconformity.

Importance of Sand Plains in Southern New England.

It may truly be said that sand plains are the most plentiful and the best-developed form of stratified glacial deposits in New England. Their abundance and relative perfection, along with their significance, make them a fitting subject for a study of late glacial history; at the same time, the relative — one might almost say complete — absence of other records of ice-front lakes in this area, such as wave-cut benches and scoured and aggraded outlet channels, makes sand plains doubly important. It is natural, then, that good work has been devoted to sand plains, and that the progress in the understanding of them has come from eastern Massachusetts.

The first clear presentation of what a sand plain is came from Davis in 1890 (a). Much detailed work is also recorded in papers by Woodworth, Gulliver, and Fuller; and more recently the correlation of sand plains, in order to make out the history of ice-front lakes, has yielded definite results to Crosby, Grabau, and Clapp. Perhaps the most concise example is Grabau's report on glacial Lake Bouvé (b), in which the history of a small ice-front lake in the southern part of the Boston Basin is rather thoroughly treated.

Discordance of Level of Sand Plains.

It is common in eastern Massachusetts to find that the sand plains in a single lake basin vary in altitude. Possibly the lakes were continually suffering changes of level by reason of temporary blocking of their outlets by icebergs or ice-dams, or perhaps as a result of great variation of supply of water from the melting ice. In that case we should expect to find deltas at all sorts of levels. Controlling conditions as irregular as the formation of ice-blockades would involve great irregularity in delta levels.

If, however, there is no such disturbing element in an ice-front lake, one can still see how the deltas in a single lake might vary in level; for if we consider again the normal lake history already outlined, we find that from the natural succession of lower and lower water-planes, as the ice retreats across the basin uncovering lower and lower outlets, there must be lower and lower sets of deltas. Sand plains, then, might mark different levels in the same lake; but in this case the variation would be perfectly systematic. Instead of a promiscuous arrangement of high and low deltas due to irregular blocking of outlets, there would be a definite grouping of deltas into sets, each set being composed of deltas of a single level or water-plane, and being succeeded by a lower set on the iceward side.

This step arrangement of deltas, in descending groups as one proceeds in the direction of ice retreat, has apparently been recognized by Grabau in his study of Lake Bouvé, and has been applied by Clapp and Crosby to the deltas of Lake Charles, Lake Nashua, and other temporary ice-front lakes of eastern Massachusetts.

The area embracing what Professor Crosby has called glacial Lake Sudbury is the field in which I have attempted to apply one or the other of these two schemes of arrangement of sand plains, — that of confusion of levels or that of horizontal steps.

Glacial Lake Sudbury.

The area occupied by the temporary glacial Lake Sudbury is a belt of lowland on the Framingham sheet (U. S. G. S.), reaching from Lake Cochituate northward to Concord. It constitutes the valley of the lower part of the Sudbury River, which at Concord joins the Assabet to form the Concord River, and as such flows north through Billerica to the Merrimac. The length of the old lake basin, from Framingham to Concord, is about eighteen miles; its average width is about four. That this basin was occupied by a temporary lake as the ice withdrew is well shown by the abundant sand plains which are scattered about in it, and which rise generally to the level of the lowest points on the rim of the basin, near by.

The approximate form and extent of the lake can best be seen on the accompanying map (Plate 5), in which the probable shore-lines are drawn along the contour which lies nearest the level of the adjacent sand deltas. Since these deltas vary nearly 70 feet in elevation, the shore-line follows different contours in different parts of the basin, as will be recognized when the map is compared with the U. S. G. S. contour map.

The country on the western side of the basin is much higher than that which forms the southern and eastern rim, being as a rule well above 200 feet in altitude. The Nashua basin, which lies west of the Assabet and Sudbury, was occupied in late glacial times by a temporary lake whose level was much higher than Lake Sudbury, and which drained eastward into it, as Professor Crosby has shown (b). The waters of Lake Sudbury, then, could not have escaped to the west; they must have reached south and east into the lower basin of the Charles River.

The divide that separates the Sudbury basin from that of the Charles has several gaps which must have been occupied either by outlets of Lake Sudbury or by arms of confluence with the contemporary Lake Charles. Near the southern end of the Sudbury basin in particular, there seems to have been, for a while at least, a confluence of the two lakes; for the present divide is itself made up of sand deltas and associated gravel deposits which appear to carry the water-plane of Lake Charles over into Lake Sudbury. This is seen on the map in the line of sand plains which extend from the big bend of the Charles near South Natick northwest through Morse's, Jenning's, Mud, and Pickerel Ponds to Cochituate. The pass at Morseville, south of Lake Cochituate, where the present divide is still lower (about 145 feet above sea-level), may also have been a point of confluence between Lake Charles and Lake Sudbury.

North of Cochituate, along the eastern rim of the basin, there are only two considerable sags or cols in the divide, — one east of Wayland, near the head of Cherry Brook, and one about a mile south of Lincoln station. Both these passes, however, are above the level of the Cochituate and Morseville passes, and so could hardly have served as outlets for Lake Sudbury unless they were originally lower, and have been subsequently raised by tilting.

Another pass occurs just outside the limits of Lake Sudbury as it is here defined, east of the point of junction of the Assabet and Sudbury (where the Concord River begins), at the head of Hobbs Brook in Lincoln. This is also a relatively high-level pass, about 160–170 feet, judging from the contours. The importance of these higher cols will be shown later.

Arrangement of Sand Plains in Adjoining Districts.

The sand plains of Lake Charles in Wellesley, Needham, and the southern part of Newton, mark a water-plane, the altitude of which is about 150–160 feet. This has been reported and discussed by Crosby and Clapp, who took their levels from the contour maps of the U. S. G. S. Boston and Framingham sheets. The recently revised map of the Boston area has made it possible to get these levels more accurately than before. A table follows which gives the altitudes in the district just mentioned, as they are shown by the newly drawn contours of the Boston map and maps of the Metropolitan Park Commission; also a few altitudes determined much more accurately by a hand-level survey, and one or two measured approximately by reference to bench-marks of the Metropolitan Water Board along the line of the Cochituate Aqueduct.

Big sand plain at Needham (Boston map, contours)	about	160′
Sand plains 1 mile N. W. of Needham “ “	“	160′
Sand plain at S. end of Waban Lake (Met. W. B. b. m.)	“	150′
Sand plain just E. of Newton Up. Falls “ “	“	150′
Sand plain north of Wellesley Hills sta. (B. map)	“	150′
Small sand plain cut by R. R., E. of Waban (hand-level)	“	154′
Big sand plain extending from Newton Centre through Eliot to Waban (lobes 500′ W. of Chestnut St. bridge 518)	“	148′
Sand plain near Woodward and Chestnut Sts. Waban		150′
Waban sand plain, E. of Newton Lower Falls (Metrop. Park. Com.)	about	150′

(Hand-level altitudes underlined.)

North of this line of plains, in general north of the Boston and Albany Circuit Railroad, there is a slight drop in the water-plane; for the well-known Newtonville plain has lobes at about 140 feet (by contours on the Boston map), and the little sand plain just northeast of Woodland station, which merges into the higher Waban plain, has lobes east of Washington Street at about the same height, as shown by the 140-foot contour. In general, however, all the plains in this part of the basin of the Charles, south of the Boston and Albany main line, are not far from 150 feet in altitude.

Near the Boston and Albany main line in Auburndale, West Newton, Newtonville, Newton, and Brighton, there is a very pronounced drop in the water-plane, marked by sand plains which lie about 80 feet lower than those just described, viz., at about 60 feet above sea-level. Most of these plains are rather obscured by settlement, e. g. those of Newtonville, Waltham, and Waverley.

There appear to be still lower plains near the Charles River, from the last-mentioned group northward, including one at Nonantum and one south of Commonwealth Avenue near Cottage Farm. The gravel plains of Cambridge and Arlington lie hardly more than 25 feet above sea-level.

This rather sudden drop from the 160–140-foot plains to those of 60 feet and under marks the change from Lake Charles into what Crosby has called Lake Shawmut (130), the smaller successor to Lake Charles, lying wholly within the Boston Basin.

North of Waltham the country east of the Sudbury basin is mostly high ground, nowhere low enough to meet the 60-foot water-plane which would be expected to mark the maximum height of temporary Lake Shawmut there. Naturally, therefore, there are no sand plains in that part of the district, between Lincoln and Lexington. The gravels farther east, in the Mystic River valley, from Arlington to Woburn, lie wholly below 60 feet.

Expectation regarding the Lake Sudbury Water-planes.

The work of Crosby, Grabau, and Clapp, on the temporary lakes of this region, pointed to the likelihood that the sand plains of the Sudbury basin would be found to be arranged according to the horizontal step scheme, i. e. either at a single altitude, marking a single water-plane, or in groups of decreasing altitude from south to north, marking successively lower and lower water-planes.

Clapp recognized from the contour map that the sand plains of both the Sudbury and the Charles basins, since they are over 150 feet, rise above the level of the Cochituate pass (145 feet), the lowest pass in the divide between the two basins; and the two lakes, Sudbury and Charles, must then have had a common level higher than the Cochituate pass, which formed a narrow arm of confluence. The line of sand plains from the Charles at Wellesley northwest to the Sudbury basin at Natick, was mentioned particularly by Clapp as representing an arm of confluence between Lake Charles and Lake Sudbury, during a stage when the water-level was about 160 feet. Clapp speaks of the deltas built in the confluent lakes in these words: —

"The plains at this stage of the confluent lakes [Sudbury, Charles, and Neponset] are by far the best developed of any stage. The broad deposits of Medfield, Millis, and Medway, as well as those in Wellesley, Needham, and West Roxbury were formed at this time. In Newton, they are developed as far north as the Boston and Albany Railroad; . . . West of Needham and Sherborn the plains extend through Wellesley, Natick, and Framingham, across the Cochituate water-parting to the valley of the Sudbury, where an extensive series of the same general elevation is found, extending even down the valley of the Concord River into Bedford and Billerica" (a, 265).

According to this, Clapp recognized the 160-foot level as one that was maintained very long in Lake Sudbury; or, to use his words again: —

"While on the west the ice had retreated as far north as Billerica, it still occupied Boston Bay and a large part of the Boston Basin" (a, 265). (See also Crosby and Grabau, 129).

If his view is correct, the ice-front, just before Lake Charles dropped down to Lake Shawmut, must have extended from near Riverside due north for about fifteen miles to Billerica. Although this extreme irregularity in ice-front is not impossible, one might rather expect that the ice would have melted back from eastern Massachusetts with its front more nearly east and west. In other words, one would naturally look for evidence that at the time the last 160-foot sand plains were formed in Lake Charles in Newton, the ice-front to the west stood somewhere in the Sudbury valley between Framingham and Concord; and that when further melting let Lake Charles down from 160 feet to the 60-foot level of Lake Shawmut, the level of Lake Sudbury fell from 160 feet to the level of the lowest pass on its rim, — the Morseville pass, at about 145 feet. In this case, the sand plains of the Sudbury valley would not mark a single water-plane, but two water-planes, the first at 160 feet the confluent stage, in the southern part of Lake Sudbury, and the second at 145 feet, the stage when Lake Sudbury was tributary to the lower Lake Shawmut by way of the Morseville pass.

From the preceding paragraphs it appears that the levels of sand plains in Lake Sudbury, according to the simple scheme of horizontal steps which Grabau used for Lake Bouvé, Crosby for Lake Nashua, and Clapp for Lake Charles, would show these features : —

(*a*) No sand plains could occur above 160 feet.

(*b*) Either the plains between Framingham and Concord would all mark a level of about 160 feet, or the plains in the southern part would be 160 feet and those in the northern part 145 feet, with possibly double-lobed plains in the zone of change from the higher to the lower level. Concerning the use of the various passes through the divide, as outlets of Lake Sudbury, this would be true : —

(*c*) The Cherry Brook and South Lincoln passes, being above 160 feet (as well as above the more southerly Morseville pass), could never have served as outlets for Lake Sudbury.

(*d*) The Morseville pass alone could have acted as a spill-way, and that only in case Lake Charles fell to Lake Shawmut while the ice-front lay somewhere between Framingham and Concord.

The Horizontal Step Scheme applied to Lake Sudbury.

The four points in the last paragraph may be considered in order:

(*a*) First, regarding the maximum height of the sand plains. According to the contours of the Framingham sheet, some of the sand plains of the Sudbury valley are above 160 feet. The splendid large delta at North Sudbury, for example, is bordered by a 180-foot contour; the large plain east of Maynard, occupied by the American Powder Company, is shown by a 200-foot contour; and the plains in Concord near Lake Walden and east of the village rise apparently to at least 180 feet. Careful levelling not only confirms the idea that these plains are well above 160 feet, but shows that many other plains which from the map might be taken as 160 feet in elevation are really 10, 15, or 20 feet above that level. A glance at the map (Plate **5**) will show this.

(*b*) The sand plains of Lake Sudbury do not fall even approximately into horizontal water-planes at 160 or 145 feet. The contours, of the U. S. G. S. map, poor as they are, express rather clearly the strong discordance of levels. Taking the contours as truthful only within 20 feet, one finds that the plains do not agree in altitude. One at Wayland, for instance, is bordered by a 140-foot contour, while that at Maynard, about eight miles further north, rises to 200 feet. The real test of accordance, however, comes when careful levelling is done to determine accurately the levels of lobe brows of the sand plains. The figures on the map (Plate **5**) show the great range of altitudes that accurate levelling brings to light. Out of sixteen different sets of lobes, measured in this way, only four measure within five feet of 160 feet, and they run all the way from 137 to 201 feet.

(*c*) Several things point to the probability that the Cherry Brook pass once drained Lake Sudbury. Just west of it in the valley, near Wayland, the level of the sand plains suddenly drops from about 190 feet to about 165 feet, the approximate level of the pass. Along the courses of brooks that head in the pass, as one follows them down-stream, are suggestions of former occupancy by more powerful streams, in the from of boulder-paved stretches, aggraded floors, and pot-holes. The detail of this evidence will be given later. While not at all strong, it is at least suggestive, when taken in connection with the better evidence of water-planes above the level of 160 feet.

(*d*) The Morseville pass near Steep Rock, and the course of the brook from that point southeast through Little's Pond to the Charles River, show no sign of scouring. The evidences of outlets are in general so poor in this region, however, that their absence here is of little weight in settling the problem.

The horizontal step scheme, therefore, does not find confirmation in the water-plane evidence in the Sudbury valley. Although this scheme has been thought to explain the grouping of deltas in the adjoining lake basins, it is distinctly the wrong explanation in the case of Lake Sudbury.

Other Possible Explanations.

Whatever theory is true for the grouping of the Lake Sudbury deltas must account for these facts: —

(*a*) The great range of level of the deltas.

(*b*) The large number of high-level deltas, 40–60 feet above the level of the Morseville pass, and 20–40 feet above Clapp's 160-foot "confluent" water-plane.

(*c*) The probable use of Cherry Brook pass as an outlet, although it stands fully twenty feet higher than the Morseville pass at the first-opened end of the basin.

These requirements seem to be met by two[1] theories, — that of irregular fluctuation of lake-level by reason of ice-dams, as already mentioned on page 273, and postglacial tilting of the land in such a way as to throw the levels of an originally horizontal step-system into confusion. Early in the field season my problem was resolved into this, — the collection of data by which I might choose between the two theories, ice-damming or postglacial tilting.

The Ice-Dam Theory.

The condition of delta levels which might be expected as a result of ice-dams or icebergs stranded in the outlets of glacial lakes has already been mentioned. Because blockades might happen at any time, not at regular intervals, the grouping of high and low deltas would be haphazard rather than systematic. By great ice-dams at the outlets the water-level could possibly be raised at times 40–60 feet above the lowest notch in the rim of the basin, so that deltas would be built at that height and higher cols might perform the duty of the one temporarily blocked by ice. One thing should be noted: although lobes might be built high above the level of the lowest col, at a time when the outlet was temporarily blocked by ice and the lake-level raised, never could lobes be built at a level below the level of the col, for the lake-level could not sink lower than that. This point is useful as a test between the ice-dam and tilting hypotheses; for by tilting extraordinarily low lobes may be produced. Haphazard grouping of levels, then, and the absence of lobes lower than the level of the lowest col, are what we should expect from the ice-dam hypothesis.

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[1] A third possible explanation has been proposed by Dr. Clapp in a recent paper on Lake Charles, — viz. a condition of extreme irregularity in the melting ice, involving a network of little lakelets at somewhat discordant levels. This will be considered in a later paragraph.

Tilting in New England presumable from Other Evidence.

Everywhere that glaciated regions have been studied in detail there is evidence of postglacial tilting. DeGeer's work on the raised shore-lines of Scandinavia prove that there, at least, the profound postglacial movements were confined almost perfectly to the area that had been covered by the ice-sheet, as if the earth's crust had sunk beneath the weight of the ice, to rise again when it withdrew (a, 66; b, 25).

In Lake Agassiz, the present slanting attitude of the old shore-lines is believed by Upham to be almost entirely the result of a rise of the land when the ice left it. These tilted shore-lines are exhaustively described and the cause of tilting thoroughly discussed in the monograph on Lake Agassiz (Upham, d). The rate of tilting is usually only about a foot per mile, but towards the northern part of the region it becomes nearly three feet per mile (d, 426, 474–486).

In the Great Lakes region, Taylor has traced the tilted water-planes of the lakes of late glacial times, and has worked out the rate of tilting. In the case of Lake Nipissing, this tilt rate is found to be only about seven inches to the mile; but in other cases it is much higher. The tilting measures most in a direction north 25° east (c, 652).

The work of Gilbert and Spencer on the shore-lines of Lake Iroquois and Lake Warren, the large temporary lakes in the region of Lake Ontario, show that the withdrawal of the ice from that district was accompanied by a very considerable rise of the land, by which the horizontal beaches were tilted into a slanting position. About Lake Ontario the shore-lines of extinct Lake Iroquois are tilted at an average rate of three and a half feet to the mile (Gilbert, 603). In the vicinity of Cape Rutland, north of Syracuse, the rate is about five feet to the mile (Spencer, 128).

In western New York, Fairchild finds that the direction of greatest tilt is between north 17° east and north 20° east (e), indicating "that the isobases of the greater area are curving lines with convexity southward." In central New York, since the Iroquois beaches in a direction less than three degrees south of east show a tilt rate of only 0.66 feet per mile, the direction of maximum tilt is apparently almost north and south. This suggests that the curve of the isobases continues eastward across New York State, and makes it seem probable that in New England the tilt would be greatest in a direction nearly due north and south, — surely only a few degrees east of north, and quite likely a few degrees west of north.

DeGeer's summary of the evidence of postglacial tilting in New England, in the form of raised marine beaches, benches, and sea-floor sediments between Massachusetts and the Provinces, is the most comprehensive and reliable study yet published. Incomplete as the evidence is, one cannot deny that there has been a postglacial uplift of the north with respect to the south. The discovery of further details, like that by Tarr and Woodworth of the beaches at Cape Ann (Tarr), will doubtless some day furnish the data for determining with more accuracy the true rate of tilt along the coast and the direction of the greatest slant. In the mean time, can we not gather valuable evidence of tilting by studying the water-planes of temporary ice-front lakes like the Sudbury, Nashua, and Charles?

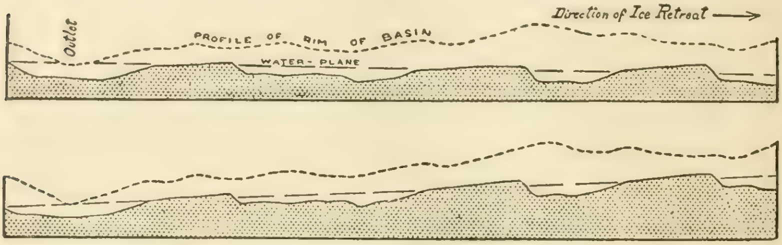

FIGURE 3.

Diagrams showing how postglacial tilting produces a discordance of altitudes among sand deltas.

In the upper figure, three deltas stand at the same altitude, marking a horizontal water-plane which is controlled by the height of an outlet at the further end of the lake. In the lower figure this region has been tilted, so that the three deltas stand at different altitudes, marking a slanting water-plane. The deltas now stand higher than the outlet col.

To sum up: From the work of Taylor, Gilbert, Fairchild, and DeGeer, we might reasonably expect that whatever evidence came to light would show a tilt towards the south of a few feet to the mile, with its greatest slant in a direction about due north and south (considerably west of the N. 17° E. line of central New York).

The Probable Effects of Tilting on Temporary Lake Features.

Taking the typical temporary lake, with its successively lower outlets and sand plains in the direction of ice-retreat, let us see how tilting will rearrange the levels.

To take the simplest case, — suppose that a single water-plane, marked originally by a set of sand deltas with brows at a common level and an outlet at a level slightly below them, is tilted evenly, with a relative elevation of the iceward side (see Fig. 3). After this movement, just as before, all the brows of the sand deltas lie in a single water-plane; but the plane is no longer horizontal, — it slants away from the ice. The sand deltas nearest the ice-field have been lifted higher than those farthest from it, the brows of the two deltas at these two extremities of the lake measuring the greatest difference of elevation of the inclined water-plane, and the deltas intermediate in position showing intermediate elevations of a measure proportionate to their distances from the two extremities. The outlet associated with these deltas, originally at or somewhat below the horizontal water-plane, will of course now be found at or a little below the slanting water-plane, as shown in Figure 3. If its position is at the further extremity of the lake (relative to the ice), or if it is at the further end of the water-plane for its stage, its level will be the lowest point marked on the water-plane; but in case the outlet was on the side of the lake, and icewards from the first delta built at that water-plane (a condition of things made possible by an irregular ice-front), its actual altitude measured after tilting will be higher than that of the sand delta whose level it once controlled (see Fig. 4).

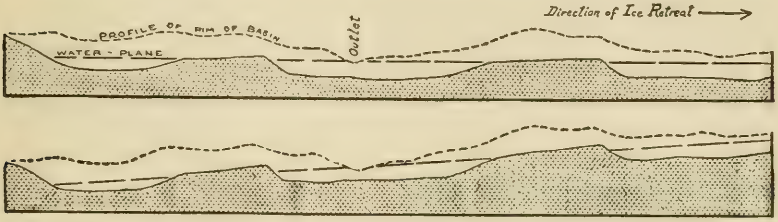

FIGURE 4.

Diagram showing how postglacial tilting, under certain conditions, may place a delta below the level of the corresponding outlet col. In the upper diagram, the ice-sheet has melted back more rapidly along the rim of the basin than in the basin itself; consequently the first delta built — the one on the left — belongs to an outlet col on the iceward side. With further retreat, a second delta has been built, on the right. In the lower diagram, the region has been tilted; and the first-formed delta has thus been brought below the level of the outlet.

Since in the lakes of eastern Massachusetts there is not usually a single water-plane, but several, it is worth while to consider how a set of these will look when tilted. In their original position, as we have seen, the deltas occur in groups, each group marking a horizontal water-plane, and standing higher than the group that lies icewards from it. Between the brow of any sand delta of the higher group and that of any delta of the lower group, there is a difference of elevation equal to the difference of the lake-level in the two stages. The outlet for each water-plane has its position just below the lobe-brow levels, and is likely to occur at or near the outer extremity of the water-plane. Now, if the region be tilted, each water-plane is tilted as already discussed, and the brows of the plains in each group will therefore indicate a rising of the water-plane icewards. The original drop from one water-plane to the next can no longer be measured by the difference in altitude between the lobe brows of any two representative deltas, for the original difference of elevation between them has been modified by the tilt. It may be that some of the deltas of the earlier, higher water-plane now stand actually lower than some of the deltas of the later, lower water-plane. The sand deltas, then, after tilting, should ascend icewards, but with a drop in elevation at each new water-plane. The relation of the altitudes of outlets would likewise be disturbed. Take, for example, any two adjacent outlets controlling the water-planes of two neighboring groups. Before tilting, the iceward outlet is the lower. The effect of tilting is to raise the lower outlet toward, to, or even above the level of its neighbor. The relative altitude of the two after tilting will depend on (*a*), the original difference of altitude (*b*), the distance apart of the outlets, measured in the direction of the tilt, and (*c*), the rate of tilting.

If the tilting of the extinct lakes was a simple uniform one, taking place after all the deltas had been built, the tilted water-planes should of course all have the same slant; in other words, the water-planes should in that case be parallel. But if the tilting was already going on during the retreat of the ice and the building of the deltas, the older water-planes at the further end of the lake would have been tilted more than the younger water-planes. Diagrammatically, the two cases would appear like Figure 5. Gilbert speaks of the application of this principle to the lakes of the Ontario basin (603).

In summing up the condition of lobe brow and outlet levels for a lake which has gone through the normal ice-front history, plus postglacial tilting, this may be said: the sand plains should be resolvable into groups, each group being composed of deltas whose lobe brows fall into a single tilted water-plane. In each group one should find, as he proceeds icewards, a steady increase of altitude of the brows, until he reaches a new water-plane in the vicinity of a lower outlet, where a sudden drop of altitude to the lower water-plane would be followed by a new group of ascending deltas. Such an arrangement may conveniently be called a slanting step-system.

Methods and Results of Levelling in Lake Sudbury.

To determine whether the Lake Sudbury deltas lie in a slanting step-system or only in haphazard fashion, a good deal of detailed levelling was necessary. Through the kindness of the Division Engineers of the various railroads and of the Engineers of the Metropolitan Water Board, I secured bench-marks which in almost every case I could conveniently use as a base, — such as the top of the rail at a certain bridge, road-crossing, or turnout, or the capstone of a culvert along an aqueduct line. From such a starting-point, with a rodman, I ran levels over a circuit as short as possible, ranging from a few hundred feet to three miles, using in some cases a surveyor's spirit-level, but more often a Locke hand-level, which proved to be a much more rapid means of levelling, and nearly as accurate. The probable error by this method was not over one or two feet per mile. On the map (Plate 5) all of these accurately determined levels and the lobe brows from which the average height has been computed are shown in black figures, while other altitudes determined by aneroid or rough computation are shown in parenthesis. These last-mentioned levels involve an error of from 5 to 20 feet. All altitudes are referred to mean low water, Boston City base.

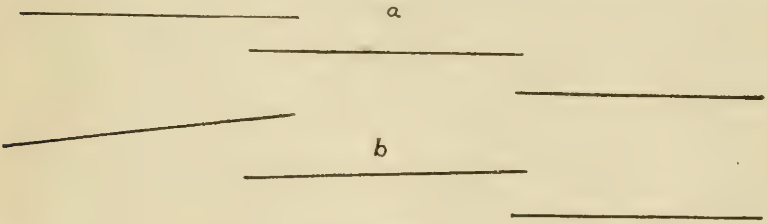

FIGURE 5.

Effect of tilting a step-system of three horizontal water-planes, (*a*) after the ice has withdrawn from the region, or (*b*) while the ice is retreating across the region. In the latter case, the water-plane which is first abandoned is tilted more steeply than its successors.

A study of the map will bring out the following facts as to the general arrangement of deltas.

In the southern part of the basin, about Lake Cochituate, the sand plains lie at about 170–180 feet, i. e., the highest lobes mark a water-plane at that altitude; but in more than one case there are lobes at different altitudes on a single sand plain, as if marking changes of level during the construction of the delta. This is remarkably true of the big sand plain just east of Saxonville, which has at least four different sets of lobes.

The two sand plains north of the last, which are cut by the Sudbury Aqueduct, and the plains northwest of them in Sudbury, are higher, — about 190 feet — although these also have one or two lower sets of lobes.

Going on towards Wayland, one finds there a sudden drop in altitude of the sand plains down to about 160 feet, represented by the three plains near Wayland station. The plain cut by the Massachusetts Central Railroad west of the Sudbury River stands at an intermediate height, however, 175 feet.

From Wayland northward through Lincoln to Concord there is a steady increase in height of the sand plains, — 160 feet at Wayland, 175 feet at South Lincoln, and 195 feet at Lake Walden. Across the river on the west side of the valley, the plains show the same sort of an increase in height going north, through 175 feet near Sudbury Centre to nearly 200 feet around North Sudbury, Maynard, and Concord Junction. Right at the north end of the Sudbury basin, where the Concord valley begins, there is a second pronounced drop in level of the sand plains from 200 feet to about 150 feet. The high plateau east of Concord village is the farthest north of the 200 feet group of deltas. Beyond that, the gravels occur only at lower levels.

In general, then, the discordance is not haphazard, as it would be if it depended on the ice-blockade theory. It is quite systematic; the plains rise from Cochituate north to Wayland, drop down there from about 190 to 160 feet, then rise steadily from 160 to 200 feet at Concord, where there is a second drop. There is a strong suggestion, in short, of a slanting step-system.

Water-Planes slanting southward, Seven Feet per Mile.

The first three sand plains to be measured with a hand-level were the Lake Walden plain (194 feet) and the two deltas east of Wayland, — one south of the railroad (161 feet), and one north (163 feet). The two deltas at South Lincoln, halfway between the Wayland plain and the Walden plain, had been found by aneroid readings to be of intermediate altitude, somewhere between 170 and 190 feet. Plotting the three accurately measured plains in cross-section, I found that they fell into a single straight line. Then, on the assumption that all the plains between Wayland and Concord had originally stood in the same horizontal plane, and that this plane had since been tilted up on the north, I plotted the position of the two South Lincoln plains, and found that in order to lie on this tilted water-plane the southern one should have lobes at 177 feet and the northern one at 180 feet. Hand-level surveys, made a few days later, fulfilled the prediction; for four lobes measured on the south plain averaged 179 feet, and three on the north plain stood at about 182 feet. Inasmuch as the circuit for this levelling, from Lincoln station to the plains and back, was a very long one — three miles — involving a probable error of three feet, the results in this case were fully as satisfactory as could have been expected. The water-plane thus determined slants southward at the rate of about seven feet per mile.

Having thus gained faith in the tilting hypothesis from the element of fulfilled prediction in levelling, I continued to collect data, and found that in nearly every case the measurements of lobes fell on slanting water-planes which passed through one or the other of the passes in the rim of the basin. The final result of this grouping of deltas is shown in Plate **4**, where all of the measured lobes are plotted to scale along a north-south line, and the slanting water-planes drawn through them. It will be seen that the Cherry Brook water-plane is determined by lobes measured on nine separate deltas. Between Wayland and Concord Junction all the deltas measured, except two, lie close to this single water-plane, as does also the Cherry Brook pass itself. The other water-planes are not so well determined; but they explain all the features save a few which will be discussed later.

On the basis of the Cherry Brook plane, then, there seem to be five parallel water-planes marked by the lobes of deltas in Lake Sudbury: —

(*a*) The water-plane of confluence between Lakes Charles and Sudbury, ranging from 150 to 191 feet (sand plain at Waban Lake to two plains cut by the Sudbury Aqueduct south of Wayland). (*b*) The Morseville water-plane, marking the stage when Lake Sudbury drained down into Lake Shawmut through the Morseville pass. This stage is shown by lobes of the plains about Saxonville and Wayland. (*c*) The Weston water-plane, marking a stage of short duration, brought about by the uncovering of part of the Cherry Brook pass before the lowest part of the pass was free of ice. The lobes that seem to mark this range from 164 to 175 feet. (*d*) The Cherry Brook water-plane, which is marked by nearly all the deltas between Wayland and Concord, ranging from 160 to 200 feet. (*e*) The Hobbs Brook water-plane, marked by the lower deltas of Concord, with lobes in the vicinity of 150 feet.

Recognizing that a grouping into seven-feet-per-mile water-planes may be incorrect, for reasons which will be brought out later, let us nevertheless trace the probable history of Lake Sudbury on the basis of a postglacial tilt of seven feet per mile towards the south. For this purpose the groups of the system of slanting steps may be considered in order of their age.

Probable History of Lake Sudbury.

THE STAGE OF CONFLUENCE. — The stage of confluent lakes which saw the birth of Lake Sudbury seems to be marked by deltas which occupy the southern part of the Sudbury basin as far north as the Sudbury Aqueduct south of Wayland. They apparently form a continuous belt from the Charles River, near Lake Waban, northwest across the divide to the Sudbury basin at Cochituate village. They also occur on the divide just south of Natick. Their distribution in the two basins in such a way as to actually form the present water-parting at Natick and Cochituate, together with the fact that the deltas are considerably higher than the Morseville pass, point to a state of confluence between the two lakes while the ice in the Charles valley was retreating towards the present position of the Boston and Albany Railroad and its front in the Sudbury valley was receding towards Wayland.

The levels of most of the plains of this stage have been determined only approximately. It has been hard to secure convenient bench-marks from which to measure some of them; consequently aneroid readings and map contours have been relied on for levels. Moreover, the plains in the southwestern corner of the basin, around South Framingham and southwest of Lake Cochituate, have not been mapped.

THE MORSEVILLE STAGE. — The drop from Lake Charles to Lake Shawmut, when the ice had withdrawn to the position of the Boston and Albany Railroad, must have caused a simultaneous drop in Lake Sudbury from the confluent level down to the level of the Morseville pass. The lowering of level seems to have come when the ice-front in the Sudbury basin was near Wayland, and while the deltas at the Sudbury Aqueduct were being built; for these have lobes at two levels which apparently fall into a water-plane with the Morseville pass and with a set of lobes on the Saxonville delta west of Lake Cochituate.

The Saxonville plain deserves special mention, for it has lobes at several distinctly different levels. On the northwest side, where these lobes are best seen, the plain has clearly been built outward towards the northwest from an ice-front at the northern end of Lake Cochituate. The occurrence of lobes in increasingly lower and lower sets on this single plain indicates that the water-level fell while the delta was being built, possibly in successive stages. The way these lobes fall on the probable water-planes of Lake Sudbury is seen in Plate **4**. Those of the highest set, at about 185 feet, are irregular, and have been measured only approximately. They seem to represent the stage of confluence. Below them, at the northwest corner of the plain, are two or three well-formed lobes, at 161–165 feet, which have a peculiar and very striking surface of cobblestones, as if all the finer sand had been washed down from them after the water-level fell. These lobes seem to fall on the Weston water-plane (the next one to be considered). Between two of them a lower lobe (at 149 feet) has been built; and this falls on the Cherry Brook water-plane. Lowest of all is a terrace with several fine lobes, at 137 feet, which have a remarkably sandy composition. On the south side of the plain, southeast of Saxonville, lobes occur at 167–172 feet, and a lower set at 152 feet. The 167-foot level, marked by at least two lobes, falls on the Morseville water-plane. The 172-foot lobe probably represents the time when the waters were just falling to the level of the Morseville pass, or when the pass was first occupied by an outlet which cut down five feet before the 167-foot lobes were formed. In all cases, the higher lobes lead down to the lower lobes by smooth slopes. It seems probable, when these lobes are identified with the various water-planes, that the Saxonville sand plain was being built forward from a large ice-block in Lake Cochituate when the main part of the ice had retreated northward beyond Wayland, and perhaps even as far as Concord.

The Weston Stage. — While Lake Sudbury stood at a level controlled by the Morseville pass, the ice-front receded from the Aqueduct plains towards the present position of the Massachusetts Central Railroad. On reaching this position it must have uncovered the pass in the Sudbury-Charles divide that is occupied by the railroad. Although this pass now stands higher than the Morseville pass (over 160 feet, whereas the Morseville pass is 145 feet), its greater height seems to be due to postglacial tilting, judging from the slant of the water-planes as marked by the lobes of deltas. As already mentioned, also, there is a pronounced drop in altitude of deltas just west of the pass in Wayland, from 190 feet to about 160 feet, the general altitude of the pass.

Before the lowest part of the pass (north of the railroad, near the head of Cherry Brook) was opened, there was of course in all probability a partial evacuation of it, along the northern slope of the high ground south of Weston village. The well-formed sand plain cut by the railroad just east of East Sudbury station has lobes at 175 feet which may very likely have been built at this time. There are lobes also on both the north and south sides of the Saxonville delta, which fall into a tilted water-plane with this 175-foot delta. That there are so few deltas marking this stage is natural enough, because it is essentially a temporary stage which was soon followed by renewed lowering of water-level as the ice withdrew so as to allow the water to pass eastward by lower paths, — first by the little forked brook half a mile northwest of Weston station, and later by Cherry Brook. These two probable lines of escape are so nearly at a common level that there has been no attempt made to differentiate two water-planes for them.

THE CHERRY BROOK STAGE. — The deltas built while the Cherry Brook pass was a spill-way mark by far the best-determined water-plane. Lake Sudbury seems to have been maintained at this height from the time the Wayland deltas were formed until the ice-front had withdrawn eight miles to Concord; for between Wayland and Concord the lobe altitudes of nearly all the deltas lie on a single slanting water-plane. The cross-section (Plate **4**) shows how closely eight of these deltas fall on the water-plane. It is also remarkable that if the water-plane be extended south from Wayland it just hits the 149-foot lobe of the Saxonville delta. This seems to show that the Saxonville delta was still being built out from the Lake Cochituate ice-block when the Cherry Brook pass was opened.

The two large plains in North Sudbury seem to be the only deltas in the northern part of the basin whose lobes do not lie on the tilted Cherry Brook water-plane. Since there is no reason to doubt the accuracy of measurement of their altitudes, they are thus far unexplained. The splendid big delta west of the railroad has lobes at 201 feet (14 to 20 feet too high for the water-plane); the delta east of the railroad has lobes at 193 feet (6 feet too high).

THE HOBBS BROOK STAGE. — It is possible that the pass at South Lincoln became an outlet to Lake Sudbury when the ice had retreated that far; but there is no evidence of it in slightly lower lobes or in signs of scouring along the courses of the brooks that head in the pass. The height of the pass, moreover, is very nearly as great as the computed height of the Cherry Brook water-plane. Consequently it seems reasonable to suppose that not until the ice had melted back beyond Lake Walden, so as to uncover a pass at the head of Hobbs Brook, three miles to the east of Concord, did Lake Sudbury suffer a marked lowering of level. With the opening of the Hobbs Brook pass, the water seems to have fallen about 50 feet, judging by the height of the lower deltas at Concord and Concord Junction. Since this new water-plane, 50 feet below the other, begins where the Concord River begins, it would perhaps be appropriate to consider the opening of the Hobbs Brook pass as marking the death of Lake Sudbury and the birth of a new lake, Lake Concord. That the transition was not immediate is shown by lobes of intermediate altitudes on the sand plains near Concord Junction.

Outlets of Lake Sudbury.

In several papers on the temporary glacial lakes of central New York, Fairchild describes a large number of well-developed outlet channels. Next to delta deposits, these channels are the clearest records of the extinct lakes of this region; and they are certainly the most striking of all. They are described as often heading in low marshy ground on a water-parting, called a "swamp col" by Fairchild (e, 36, 37, 38, 58, 61). As channels with definite walls, they run often nearly straight for a mile or so. One which drained Naples Lake, given as a good example of an abandoned river-bed, is described as "over a mile long, 20 to 25 rods wide, with banks 15 to 25 feet high, and a flood plain of varying width," and a "pavement of cobbles and boulders in the bottom of the channel," which "is still well shown through the vegetal accumulation" (a, 362). When, as in this case, the channel is cut in drift, the banks and flood plain seem to be well developed. Not infrequently, however, a channel has rock walls and a swampy bottom. Some of the old outlets of Genesee Lake are rock gorges with swamps partly occupying the channel floors (c, 434, 435, 436, 437, 438). In certain cases, deltas built into these channels from side ravines have levels of from 70 to 80 feet above the channel floor, seeming to indicate a down-cutting of the floor 60 to 70 feet since the channel first opened (c, 435). Other outlets of Genesee Lake are broad, with flood plains. At the lower ends of these channels are commonly plains or deltas of detritus, built out by the stream which cut the channel above (e, 38, 52, 54). One at Cedarville is more than a square mile in area. Most striking of all are the deep rock gorges at Syracuse, which mark outlets of glacial Lake Warren. One of these is two miles long, 8,000 to 10,000 feet wide at the bottom, and 125 to 150 feet deep, with nearly vertical walls; another is a limestone gorge, with a cataract cliff 160 feet high, at the foot of which is a deeply excavated pool (e, 60).

In New England, the outlets of temporary lakes are not nearly so well defined. In the case of Lake Nashua, Crosby has discovered what he considers to be evidence of outlet scouring in the pass at Clinton, — a sag in the divide, which must have been used as a spill-way, judging from the height of sand plains in the Nashua valley near by. Professor Crosby says: "This is an ideal outlet — narrow, well-defined, and with every indication of a strong stream flowing swiftly down around Snake Hill into the valley of North Brook. In the lower part of its course, especially, this stream washed away all the fine parts of the till, and its path is now strewn with thousands of residuary boulders. That this is the work of a long-continued torrent, and not of some transitory cloudburst, is proved by the pot-holes to be seen in the bed at North Brook at West Berlin, in situations which make it well-nigh impossible that they can have been formed by the modern brook" (a, 318).

Similar traces of spill-ways are to be seen in some of the cols in the eastern rim of Lake Sudbury, and along the courses of the brooks that head in them. A half-mile northwest of Weston station, the contours show a forked pass at about 160 feet, occupied by the headwaters of a brook and crossed by a road that runs north from the village. According to the contours, this col is the lowest northeast of the Saxonville pass, being probably 10 feet lower than the one south of Weston village. It is therefore a place which deserves critical examination for evidence of outlet scouring.

Going north along the road from the railroad west of Weston station, one crosses the western end of a ridge of bed rock with a thin till covering. Reaching the southern fork of the brook, one finds west of the road a broad swampy area, well wooded and almost flat, at an elevation of 163 feet (aneroid). Beginning directly at the road and extending east along the line of the brook, is a pavement of boulders so thick as to be remarkable even to one not looking for features of the sort. The paved zone is about 100 feet wide, and consists of boulders of moderate size, as well as a few cobbles. It follows the lowest ground along the brook, which is about 3 feet wide. About 300 feet east of the road, the pavement rather suddenly stops, and the course of the brook is through a narrow grassy flat, which soon broadens out into a broad swamp at the junction of the two headwater forks. The absence of boulders and blocks along the brook just up-stream may be largely or wholly due to the construction of a private road across the brook about 300 feet east of the highway, — the rocks having been collected for its construction. Where the northern of these two brooklets crosses the road, one finds on the west side of the road, going up-stream, a few bare ledges and many blocks, including some large boulders, and beyond these the flat swampy ground already mentioned as the source of the brooklets. The elevation at the road at this point is 165 feet (aneroid). Going down-stream from the road, one finds a pretty continuous boulder pavement as far as the broad meadow at the junction of the two brooklets, though the boulders are much thicker in some places than in others. There are a few bare ledges here, also.

On both these brooklets the boulder pavement is a distinct and striking feature. There is no such abundance of blocks on the slopes which lead away from the brooks to the north and south. The distribution is emphatically along the two lines of lowest ground; and the width of the pavement together with the general good size of the boulders seems to indicate that scouring much stronger than that of the present little stream has gone on in the past, washing the finer parts of the thin till cover down-stream, and leaving bare ledges and a thick pavement of boulders. There are no steep banks, however, enclosing the paved zone, such as one might expect to find.

Down-stream from the junction, the brook follows generally a rather broad flat meadow; and though boulders may once have been plentiful at certain points along its course, there is no longer anything like the boulder pavement seen up-stream. From the railroad for about 500 feet southward along the brook, however, there are a good many boulders, possibly of some significance. Below this the valley becomes extremely broad, flat, and swampy. These flat meadows along the brook are evidently aggraded parts of its valley; and they may have been built up by the supply of gravels and fine material from the scoured boulder-paved pass up-stream.

Along the course of Stony Brook, in several places, particularly between Kendal Green and Roberts, there are stretches of boulder pavement similar to those just described. Doubtless the brook gets its name from this fact. Moreover, the two large pot-holes beside the railroad embankment, near the northern end of Stony Brook Reservoir, may have been formed by the action of a powerful stream that was the outlet for Lake Sudbury. Whatever water spilled over at Weston, down Cherry Brook, at South Lincoln, or at the head of Hobbs Brook, would have run into Stony Brook; and marks of scouring, such as boulder pavements and pot-holes, should be expected wherever the course of the stream was down a steep slope.

Heading on the southeast side of the Hobbs Brook pass, Hobbs Brook flows south into Stony Brook, a large part of its course having been dammed up to form the Cambridge Reservoir. On the northwest side of this reservoir, about a mile north of Prospectville, near where the parkway joins Concord Avenue, is a small exposure of bare rock, rounded and hummocky, as if worn by a powerful stream. About a quarter of a mile below the reservoir, along the course of the brook, is a pavement of boulders about 100 feet wide and 300 feet long, — again suggesting the former occupancy of the course of Hobbs Brook by a powerful stream at a time when the pass above it served as a spill-way.

Similar evidences might be expected below the Morseville pass, in the brook that drains Little's Pond, but I have looked in vain for them. The brook that heads in Weston village shows no sign of scouring. Just where its course begins to be steep, a millpond has been formed, and the aspect of the ground is otherwise changed by artificial grading. Cherry Brook exhibits no boulder pavement.

Direction and Rate of Tilt is questionable.

Judging from the fact that 8 of the 11 accurately levelled deltas between Wayland and Concord fall nearly in line for a single water-plane when plotted with respect to a north-south line, as in Plate **4**, and that they do not harmonize so closely when plotted with respect to any other direction, it seems safe to say that the direction of maximum tilt is somewhere about due north and south. The rate of tilt measured along this slanting water-plane of the Cherry Brook stage is a little over 7 feet per mile, steeper than what might be expected from the evidence of Gilbert, Fairchild, and DeGeer. The other water-planes all lie parallel to this well-defined Cherry Brook plane, — that is to say, the same tilt is recorded by all.

Over against the striking conformity of delta levels to the 7-feet-per-mile water-planes, there are a few details which suggest that the tilt is even steeper and the grouping consequently somewhat different from that just given.

Two fairly well developed deltas at North Sudbury which should fall on the Cherry Brook water-plane if the other deltas are correctly grouped, stand 6 and 14 feet too high, respectively. These were carefully levelled, and there is no reason to doubt their altitudes, 193 feet and 201 feet. Ice-damming might account for this, or it is possible that the deltas were built in a little high-level lakelet held in by an irregular ice-front against the western side of the valley, but there is nothing to support these explanations save the necessity for them. Tilting could explain the extraordinary height just as well, — but not tilting at the rate of 7 feet per mile.

The extraordinarily low lobes on the northern side of the big Saxonville delta, at 137 feet, have already been spoken of; but their altitude has not yet been explained. These five or six lobes are unusually well formed, and compel attention. On seeing them, my first idea was that they belonged to the Cherry Brook water-plane; but that plane, if extended southward from Wayland with the 7-feet-per-mile slant, hits the Saxonville delta at 149 feet, where there is one lobe, to be sure, but only one, and to all appearances a lobe that registers simply the transition from one long-lived water-plane, here 163 feet, to another permanent water-plane at 137 feet.

Curiously enough, the "too low" lobes of Saxonville and the "too high" 201-foot delta of North Sudbury can be brought by plotting into a single slanting water-plane which passes through the two Wayland deltas and just above the Cherry Brook pass, as shown in Plate **3**. The Cherry Brook water-plane thus drawn has a slant of over 11 feet per mile. The deltas in Lincoln and Concord falling below this steeply inclined water-plane might perhaps owe their level to an outlet through the South Lincoln pass.

Drawing other 11-foot-per-mile planes for the higher Saxonville lobes, one gets some curious surprises in the way in which lobes fall on single water-planes; but the difficulties in explaining the occurrence of these water-planes are so great, and the slant of them is so extraordinarily steep, that little faith can be placed in them.

Plotting the delta levels with respect to an axis in any other direction seems to bring no better results. Further detailed work is needed, if they are all to be brought into perfect harmony with a single slanting step-system.

While the 137-foot lobes are so troublesome, in being too low for their water-plane, they have a peculiar value. Their altitude is a little below that of the very lowest col in the divide, — the Morseville pass, — which, judging from data secured from the Metropolitan Water Board, must be over 140 feet. As mentioned on page 281, this condition of things seems to be explainable only by tilting.

The Theory of Many Lakelets.

In a recent paper on the sand plains of glacial Lake Charles, Clapp states his belief that the ice melted off from eastern Massachusetts in an extremely irregular fashion, so as to form a network of marginal lakelets, in which, here and there, the deltas were built. This theory seems to account for the prevalent discordance of altitude in neighboring deltas; and it is based on observations which Clapp sums up under four heads (c, 207). In reviewing these features in order, let us consider whether they are to be seen in Lake Sudbury or not.

(1) The plains in the northern part of Lake Charles, according to Clapp, are distinctly marginal in their position, — grouped about the shores and islands of the extinct lake, as if they had been built not in an open water body but in single lakelets which formed along the sides of the basins while the ice still occupied the central portions. This marginal distribution of sand plains is not distinctly the rule in Lake Sudbury. Most of the large deltas are not far from the rim of the basin; but since there was shallower water near the rim, it is natural that there the deltas were most quickly built and thus grew to largest size.

(2) Clapp remarks that in several cases the ice-contact slope extends clear around the sand plain, except on that side where there is higher ground. In some cases there is an approach to this in Lake Sudbury — e. g. the large Wayland plain, the Walden plain, and the sand plain which lies a mile due west from South Lincoln station; but as a rule about half the border of a delta in ice-contact and the rest is either definitely lobate or flattish, as where there was shallow water.

(3) Typical deltas in Lake Charles are said to be associated with effluent eskers on the south, marking the course of subglacial or superglacial outlets of the lakelets. The supposed connection of a number of lakelets by these streams accounts for the fact that although no two deltas are at exactly the same level, the discordance of their altitudes is slight. In the Sudbury valley, feeding eskers are common. Effluent eskers are rare. One which runs southward from the southeastern corner of Walden Pond connects the main Walden plain with the plain at Baker's Bridge. The plain one mile due west of South Lincoln station may have been enclosed by ice on all sides; for its southern

border is steep, and several effluent eskers extend out from it. These two cases, only, have been noted in Lake Sudbury as delta deposits which may well have been built in small ice-enclosed lakelets whose outlets on the southern side, through tunnels, perhaps, are marked by eskers. This condition of things, however, is the exception. The sand plains in nearly every case have well developed lobate borders on the southern side, which were clearly built not against an ice-wall, but in open water. Often they have been built forward so far as to nearly overlap the northern end of an older esker. This occurs, for instance, at the western end of the largest South Lincoln plain. Here, as is usual elsewhere, the margin of the plain is not continuous up to the head of the esker; there is a gap of a few hundred feet between the two. Instances have been noted (Woodworth) of cross-sections in sand plains which show where an esker abandoned by the withdrawal of the ice was subsequently buried by the forward extension of a sand delta. In a region where sand plains and eskers are abundant, this overlapping of eskers by deltas is almost inevitable. The mere topographical connection of the two sorts of deposits, therefore, does not prove that they were contemporaneous and that the "effluent" eskers mark outlets rather than inlets; unless as in the Walden plain, the border of the delta, near its junction with the esker, is an ice-contact rather than a lobate border. Aside from the two cases cited, there is nothing to suggest that the eskers in Lake Sudbury are other than feeding eskers. Frequently the eskers broaden out into gravel fans, at intervals, as is shown on the map. Some of these fans may well represent local lakelets in the much decayed ice; but I am inclined to think that as a rule even the fans are true ice-front deposits, built by successive stages at the continually receding mouth of a subglacial tunnel.

(4) "The elevation of all the plains of the system in this part of Lake Charles is very nearly or quite uniform, at about 150 feet above tide." (Clapp, c, 208). Clapp's own figures, however, place the range of discordance of altitudes at no less than 30 feet, — from 140 to 170 feet. This imperfect accordance of altitudes is thought to indicate a state of imperfect connection between the lakelets, by super- or subglacial streams.

Such an explanation whether correct or not, is certainly convenient. It might be successfully applied to any group of discordant sand plains, where the discordance amounts to even more than 30 feet. Recognizing, therefore, that this theory would account for the differences in delta levels in Lake Sudbury, one is tempted to ascribe all discordance there to a network of lakelets and decaying ice-blocks. The frequent occurrence of deltas with lobes at two or more levels favors this theory; moreover, the extraordinary case of the Saxonville plain has already been explained as due to the wasting of an abandoned ice-block in Lake Cochituate.

On the other hand, the remarkable way in which the many lobe altitudes fall into line, when plotted as in Plate 5, favors the idea that the discordance of levels, on the whole, is not irregular but systematic, — not so satisfactorily explained by isolated lakelets and wasting ice-blocks as by wide open lakes and an ice-front which lay essentially east and west.

Summary.

My conclusions from this study of the sand plains of the Sudbury valley are these: —

(*a*) In late glacial times the basin was occupied by a temporary ice-front lake.

(*b*) This lake underwent successive lowerings of level, in a manner that may be deduced after the horizontal step scheme. At each stage, deltas were built. In some cases, changes of level occurred while the delta was under construction, — notably in the Saxonville sand plain, because that was built forward from a huge ice-block which occupied part of Lake Cochituate long after the main ice-sheet had left it.

(*c*) Perhaps partly during the formation of the deltas — at any rate, after it — the whole region was tilted towards the south. By this tilting apparent confusion of altitudes of the deltas was brought about; but this discordance, when studied with proper accuracy and detail, is seen to be systematic. The tilt seems to be greatest in a due north-south direction, at the rate of about 7 feet per mile.

Further detailed work, in determining the altitudes of the best lobes of a great number of sand plains in the extinct lake basins, ought to demonstrate the truth or incorrectness of the tilting hypothesis. In view of the fact that tilting to some degree is almost certain, from evidence in other parts of glaciated North America and along the New England coast, and that even a short field study of the seemingly discordant deltas in the Sudbury valley goes far towards converting disorder into system, it appears that the grouping of sand plains in eastern Massachusetts may deserve even closer attention than it has usually received.

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PLATE 1.

A. Lobate front of the big Saxonville delta, at its southwestern side. The three high lobes are about 170 feet in altitude, and probably belong to the Morseville water-plane. Just to the right of the house, and below it, is a lower lobe which belongs to one of the lower water-planes.

B. Water-worn surface of a ledge near Hobbs' Brook reservoir, mentioned on page 294. This may possibly record the work of a torrential outlet of Lake Sudbury.

A. [illegible] CUT [illegible]LLE

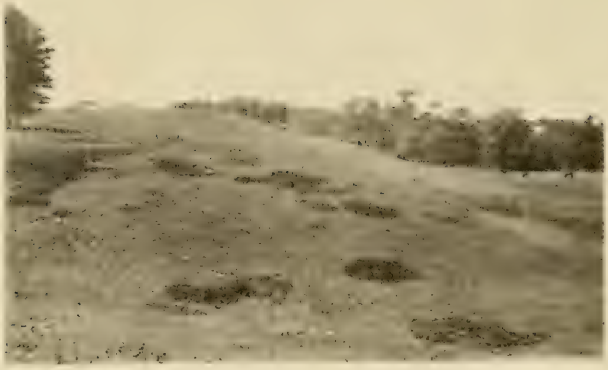
B. WATER-WORN LEDGE NEAR [illegible]

HELIOTYPE CO., BOSTON.

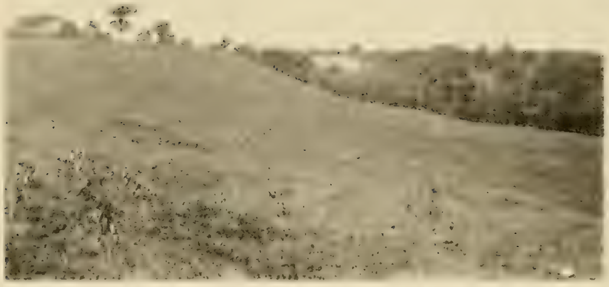
PLATE 2.

A Double lobe-border of the big Saxonville delta at its northwestern corner (see pages 289 and 295). In the foreground is one of the low (137-foot) lobes, sloping down to the flood-plain of the Sudbury River, on the right, where horses are grazing. Beyond, in the centre of the picture, the doubly lobate front is seen in profile, — the higher 161-foot lobe sloping smoothly down to a 137-foot lobe.

B. Another view of the northwestern border of the Saxonville delta. The same 161-foot lobe is seen nearer than before; and part of the frontal slope of another lobe of the same group (165 feet) in the immediate foreground. On the right is the 137-foot terrace. Exactly in the centre on the picture, the intermediate (149-foot) lobe is very indistinctly shown in profile, occupying an interlobate hollow between the two higher lobes.



A. DOUBLE LOBE-BORDER NEAR SAXONVILLE.



B. LOBES NORTH OF SAXONVILLE.

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PLATE 3.

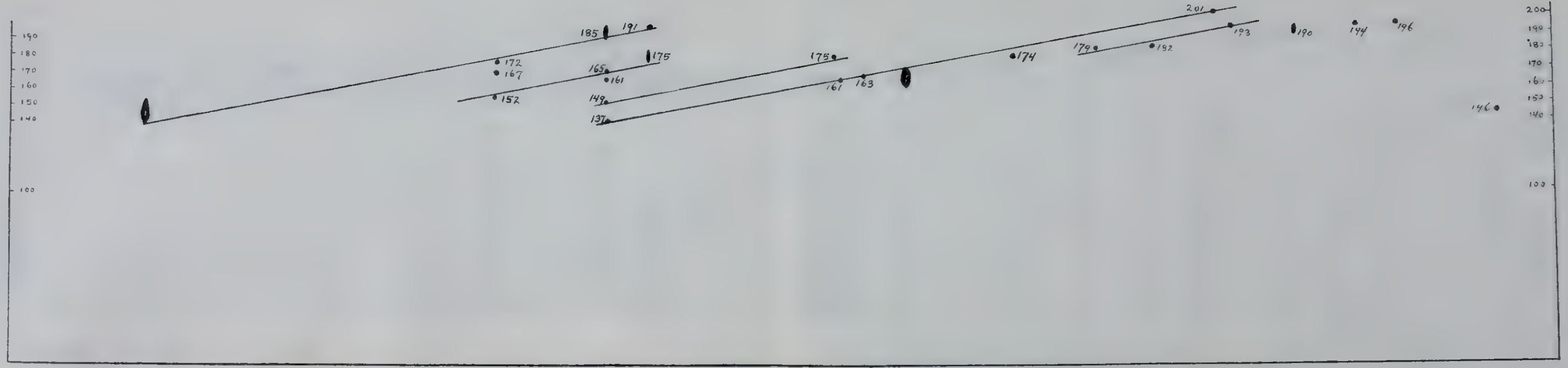
Tilted water-planes of Lake Sudbury. The significance of this diagram may best be seen by superposing it on Plate **4**, to which it is supplementary. It shows how the same points, plotted as in Plate **4**, might less perfectly be grouped into a series of more steeply tilted planes, which slant about 13 feet to the mile. (See page 295.)

PLATE 4.

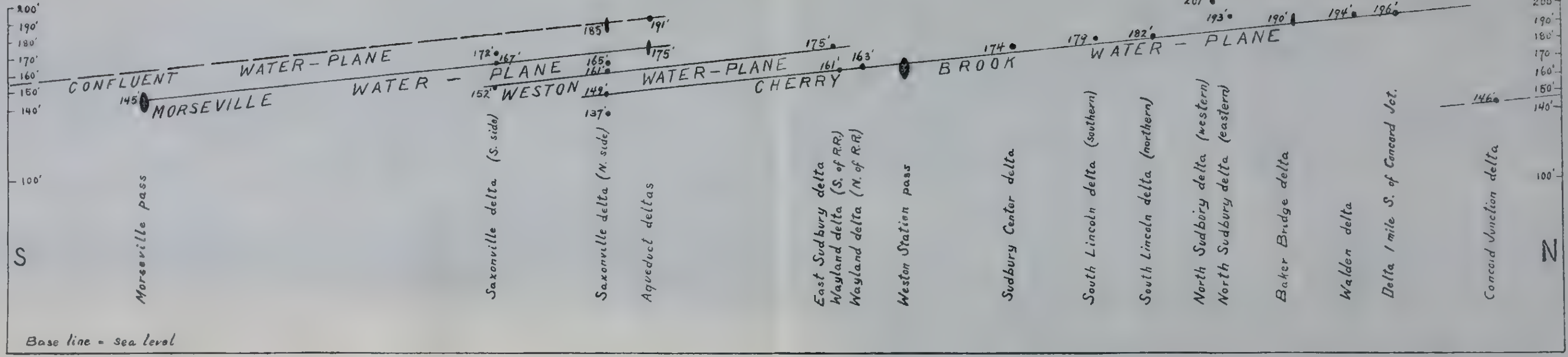
Tilted water-planes of Lake Sudbury. The altitudes of lobes and outlets, given on the map (Plate **5**), are plotted in profile, with reference to a north-south line. The points fall close to a series of planes which rise northward at the rate of about 7 feet to the mile. The horizontal scale is the same as in Plate **5**; vertical exaggeration about 75.

Goldthwait. Glacial Lake Sudbury

Plate 3



TILTED WATER-PLANES OF LAKE SUDBURY.

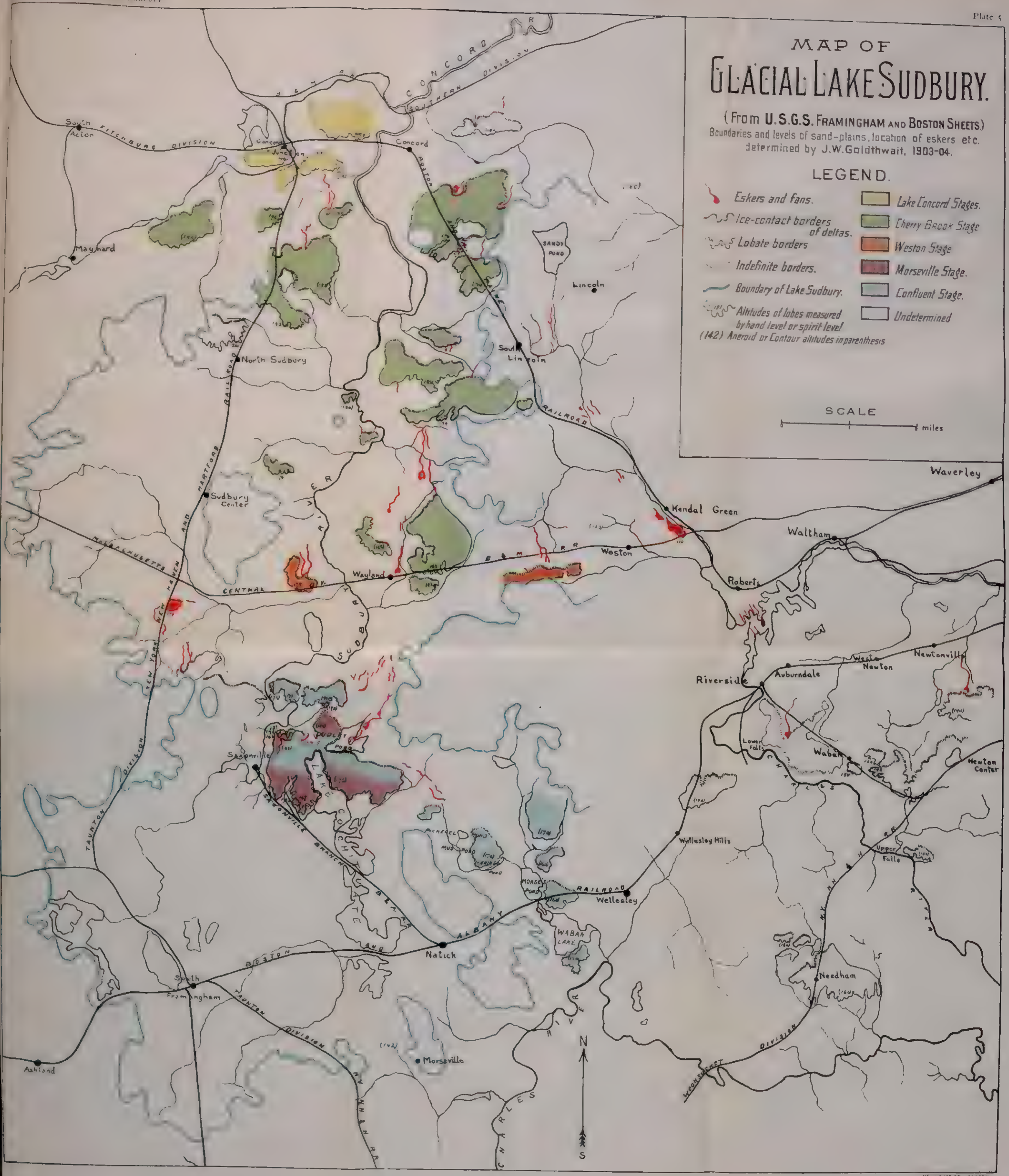


TILTED WATER-PLANES OF LAKE SUDBURY.

PLATE **5**.

Map of Glacial Lake Sudbury, showing the probable boundary of the lake and the distribution of sand plains and eskers within its limits. The altitudes of lobes and of passes in the rim of the basin are given in feet (above mean low water, — Boston City base). The separation into groups, marking several successive water-planes, seems justifiable in view of the data presented in this paper, and summed up in Plate **4**.

Plate 5



MAP OF GLACIAL LAKE SUDBURY.

(From U.S.G.S. FRAMINGHAM AND BOSTON SHEETS.)
Boundaries and levels of sand-plains, location of eskers etc.
determined by J.W. Goldthwait, 1903-04.

LEGEND.
Eskers and fans.
Ice-contact borders of deltas.
Lobate borders
Indefinite borders.
Boundary of Lake Sudbury.
Altitudes of lobes measured by hand level or spirit level
(142) Aneroid or Contour altitudes in parenthesis
Lake Concord Stages.
Cherry Brook Stage
Weston Stage
Morseville Stage.
Confluent Stage.
Undetermined
SCALE
miles
N
S
Concord
Concord Junction
South Acton
Maynard
North Sudbury
Sudbury Center
Lincoln
South Lincoln
Sandy Pond
Kendal Green
Weston
Wayland
Waverley
Waltham
Roberts
Riverside
Auburndale
West Newton
Newtonville
Newton Center
Lower Falls
Waban
Upper Falls
Wellesley Hills
Wellesley
Needham
Saxonville
Lake Cochituate
Dudley Pond
Mickerel Pond
Mud Pond
Morses Pond
Waban Lake
Natick
South Framingham
Ashland
Morseville
Fitchburg Division
Southern Division
Boston and Maine Railroad
Massachusetts Central
B & M R R
New York New Haven and Hartford Railroad
Taunton Division
Saxonville Branch
Boston and Albany Railroad
Woonsocket Division
N Y N H & H R R
Concord R
Sudbury River
Charles River

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